Atomic Energy Control Board
P.O. Box 1046
Ottawa Canada
K1P 5S9

Commission de contrôle de l'énergie atomique
C.P. 1046
Ottawa Canada
K1P 5S9

INFO-0414

COMMUNICATIONS INVOLVING THE CONTROL ROOM OF A NUCLEAR POWER PLANT

(AECB Project No. 2.212.1)

by

J. MacGregor, B. Cunningham,
F. Safayeni and R. Duimering

CORE, Inc.

A research report prepared for the
Atomic Energy Control Board
Ottawa, Canada

Published April 1992

Canada

Research report

COMMUNICATIONS INVOLVING THE CONTROL ROOM OF A NUCLEAR POWER PLANT

A report prepared by Jim MacGregor, Bart Cunningham, Frank Safayeni and Rob Duimering, CORE, Inc., Vancouver, under contract to the Atomic Energy Control Board.

ABSTRACT

This study investigated communications within the operations component of a nuclear power plant, with a primary emphasis on control room communications. A structured interview technique was developed following preliminary interviews at the plant, and pretested at AECB headquarters. Patterns were identified from questions asked on communications links, work relationships, miscommunications, procedures, instrumentation and responses to problems. The study was an exploratory one, conducted under a limited budget, to provide background information and to identify areas for further investigation. The report offers recommendations about areas for further research.

RÉSUMÉ

La présente étude visait à examiner les communications dans le cadre des activités d'une centrale nucléaire et principalement des communications dans la salle de commande. On a mis au point une méthode d'entrevue structurée après avoir procédé à des entrevues préliminaires à la centrale et en avoir éprouvé l'efficacité à l'administration centrale de la CCEA. À partir des questions posées, on a pu établir des modèles sur les liens de communication, les rapports de travail, les malentendus, les procedures, les appareils et les réponses aux problèmes. L'étude de nature exploratoire et au budget limité visait à recueillir des données fondamentales et à déterminer des domaines à approfondir plus en détail. Le rapport présente d'ailleurs des recommandations sur de nouveaux projets de recherche.

DISCLAIMER

The Atomic Energy Control Board is not responsible for the accuracy of the statements made or opinions expressed in this publication, and neither the Board nor the authors assume liability with respect to any damage or loss incurred as a result of the use made of the information contained in this publication.

COMMUNICATIONS INVOLVING THE CONTROL ROOM OF A NUCLEAR POWER PLANT

EXECUTIVE SUMMARY

The study investigated communications within the operations component of a nuclear power plant, with a primary emphasis on control room communications. Data was collected through interviews with thirty people from two of the five shift crews at Bruce "A" nuclear power station, representing nine different organizational roles within the operations component -- Shift Supervisor (SS), Shift Operating Supervisor (SOS), Shift Maintenance Supervisor (SMS), Authorized Nuclear Operator (ANO), Supervising Nuclear Operator (SNO), Supervised Control Panel Operator (SCPO), Nuclear Operator (NO) and operators from Unit 0 (U-0) and Fuel Handling (F-H). A structured interview technique was developed following preliminary interviews at the plant, and pretested at AECB headquarters. The interview asked questions on communication links, work relationships, miscommunications, procedures, instrumentation and responses to problems. Each interview lasted approximately one hour.

1. Main Findings

1.1 Communication Linkages: Patterns of communications were identified from two perspectives -- what a "source" position reported about "target" positions, and what target positions reported about a source position. There was a high degree of consistency between the two points of view. From an analysis of this data it appeared that the ANO position plays a central role in communications, followed by the SOS position. Both are heavily involved in communications with almost all other positions on a routine basis. Communications are particularly intense at the beginning and end of a shift.

Almost all of the reported communication links fell within the boundaries of the operations component. Communication links with other components, such as the Technical Unit or Planning, appeared to be weak.

1.2 Work Relationships: Respondents were asked about actions of others that were helpful, or not-so-helpful, in doing their job. On the basis of this information we identified patterns of "task dependencies". (A "task dependency" is understood to exist between jobs when the manner in which one job is performed can affect performance of the other.) The resulting network of task dependencies was highly similar to the network of communications, and identified the ANO position as the one which could most affect, and be most affected by, other positions. The types of positive and negative actions which people mentioned were classified into 12 categories, which in turn fell into three major areas,

(i) providing information (42% of the actions cited),

(ii) organization of tasks/priorities/people (35%), and

(iii) personal ability/expertise (23%).

The ratio of positive to negative comments was two to one. Comments about (i), information providing, were equally distributed across all positions, reflecting a widespread and strong emphasis on this type of activity. Comments about (iii), personal ability, also showed no particular association with specific positions. Comments about (ii), organization, however, were not equally distributed, with most being made by ANOs and NOs, and most being made about SNOs and ANOs. This pattern may reflect issues related to the New Operating Structure.

Respondents also commented on other aspects of the organizational environment. Thirty-three of these comments (36% positive and 64% negative) were specifically about the New Operating Structure. Most of the positive comments were about increased supervision/experience in the field. Most of the negative comments were about impacts of the New Operating Structure on the control room, division of responsibility and the status of the negotiations. Fifty-six comments were made about other components within the plant (Management, Planning and the Technical Unit). The majority (70%) could be described in terms of five categories -- working conditions, size of bureaucracy, communication/contact, realism of decisions/plans, and shifts. About 75% of these were negative, and most of these negative comments were about lack of contact with, or understanding of, the operation component by other components. This is consistent with the absence of linkages which emerged in the analysis of the communication data, reported above (Section 1.1, Communication Linkages).

1.3 Command Structure: Every one of the 30 interviewees reported that they were organized under the New Operating Structure. One of the major innovations of the new structure has been to eliminate the position of Second Operator and to create the position of field SNO, whose major duty is to provide supervision in the field. Our understanding is that this has involved changes in authority and communication structures. One change is a direct line of reporting between the SOS and SNO for matters of personnel supervision. The major communication and task dependency linkages that emerged from our analyses were consistent with the new structure, except that a relatively strong link remains between the ANO and NO positions. This linkage was not explicit in the New Operating Structure, so far as we are aware. As a result, the organizational principle of unity of command appears to be violated in two ways, in that the link from SOS to SNO bypasses the ANO, the SNO's direct supervisor on work direction issues, while the link from ANO to NO bypasses the SNO, the NO's direct supervisor on field activities. The potential advantages of the new structure include: increased supervision in the field; increased expertise in the field; decreased indirect supervisory load on ANOs. Potential disadvantages include ambiguity of reporting relationships (in both the SOS-ANO-SNO relationship and the ANO-SNO-NO relationship) and reduced expertise in the control room. There may also be communication and information processing problems associated with the position of Supervised Control Panel Operator (SCPO) created under the New Operating Structure. Linkages between this position and others appear to be very weak. In addition, interviewees reported that because SCPOs work on two units, information sometimes gets confused.

1.4 Procedures and Instruments: Generally, operators are highly reliant on the procedures and instruments that are available to do their jobs. However, there are concerns about instrument reliability and an over-reliance on procedures. Operators also made several positive comments about the visibility of instruments and their layout, although they offered a number of criticisms which might improve reliability and the types of instruments and dials which might be used. A number of respondents mentioned procedures for reporting, and a concern was raised that reports have become less intelligible now that they have to be entered in BIMS (Bruce Information Management System).

Overall, the results point out the need to design procedures and instruments which would help the operators to perform their job more efficiently. The comments also indicated a need to involve operators in the design of procedures and instruments which are more "user friendly."

1.5 Diagnosing Difficult Events: The events which respondents found most difficult to diagnose were more systemic and complex, and seemed to emerge from the integrated functioning of various systems, parts, and machines. Such problems could not normally be resolved through existing procedures. The majority of respondents suggested that consultation and the input of other people were important to discovering ways to resolve such problems.

1.6 Miscommunications: Interviewees were asked to identify some of incidents where miscommunications occurred. Five general types of incidents were identified: assumptions differing, priorities differing, misunderstandings, omissions, and being ignored. Most of the suggestions for reducing miscommunications referred to forms of training which emphasized group work, verbal communications, written communications, and general suggestions. These results support the findings in others sections which indicate that much can be done to develop "group" procedures to complement the available technical procedures.

2. Recommendations

2.1 As discussed in 1.1, the links between the operations component and other organizational components appear to be weak. If this is the case, then these relationships should be further examined. However, it might be wise to confirm this finding with information collected from other parts of the organization, about their communications and relations with the operations component.

2.2 The effectiveness of the New Operating Structure is something that should be monitored from time to time. The related issue of the SCPO position is something that might be looked at (see 1.3).

2.3 It may be worthwhile to examine procedures for reporting. One context in which this could be done is that of BIMS (see 1.4 above). The complaint was made that reports have become less intelligible now that they have to be entered in BIMS. The present paper discusses ways of measuring intelligibility and of testing this claim. If it were supported then it may be necessary to develop procedures (and aids) covering BIMS reporting.

2.4 As presently organized, control room and field operators on the nuclear units rotate through the units. An alternative form of organization would be to dedicate operators to particular units. Both forms of organization have potential advantages and disadvantages. Nevertheless, dedicating personnel to specific units might improve communication and information processing. Miscommunications due to confusing information about units (or confusing the physical units themselves!) would presumably be reduced. Unit "teams" might develop a body of unit-specific terminology that was more precise and more consistent than present terminology. Linkages with other components might also be strengthened, if unit teams included personnel from Planning or the Technical Unit, for example. This is a large issue. It could be investigated theoretically, by identifying and analyzing the various implications of different work designs, and empirically, by directly comparing two or more plants organized along different principles.

TABLE OF CONTENTS

Page

ABSTRACT i

EXECUTIVE SUMMARY ii

TABLE OF CONTENTS vi

LIST OF DIAGRAMS, FIGURES, & TABLES viii

1. INTRODUCTION 1

1.1 Background 1
1.2 Objective 2
1.3 Tasks to be Performed 2

2. PROCEDURE 3

2.1 Analysis 4

3. RESULTS - I 5

3.1 The Key Roles and Interactions in Control Room Communications 6
3.1.1 A Typical Shift in the Control Room 6
3.1.2 Quantitative Analysis of Communication Linkages 8
3.1.3 Amount of Communication Based on Other Estimates 15
3.1.4 Communication with Other Components in the Plant 16

4. RESULTS - II 16

4.1 Requirement 1 -- Coordination and Dependence on Others 17
4.1.1 Dependencies within the Production Unit 17
4.1.2 Patterns of Dependency Linkages 22
4.1.3 Dependencies of the Production Unit on Other Components of the Organization/Industry 25

4.2 Requirement 2 -- Carrying Out the Work Effectively 31
4.2.1 Positive Comments about Procedures 31
4.2.2 Not-so-positive Comments about Procedures 33
4.2.3 Suggestions for Improving Procedures 34
4.2.4 Positive Comments about Instruments 34
4.2.5 Not-so-positive Comments about Instruments 36
4.2.6 Summary: The Usefulness of Procedures and Instruments 37

4.3 Requirement 3 -- Diagnosing Routine and Unusual Events 37
    4.3.1 Summary: Diagnosing Difficult Problems 38

4.4 Miscommunications and Reactions to Information Overload 40
    4.4.1 Reasons for Miscommunications 40
    4.4.2 Suggestions Offered for Reducing Miscommunications 43
    4.4.3 Summary: Communication and Overload 44

5. DISCUSSION 45

5.1 Specific Tasks 45
    5.1.1 Command Structure 45
    5.1.2 Methods for Measuring Intelligibility and Understanding in Control Room Communications 49

5.2 A Socio-Technical View of Organization Design 51
    5.2.1 Compatibility -- Usefulness of Procedures and Instruments 51
    5.2.2 Minimal Critical Specification of Procedures 52
    5.2.3 The Socio-Technical Criterion in Dealing with Problems 53
    5.2.4 The Multifunctional Principle -- Organism vs. Mechanism 53
    5.2.5 Boundaries -- Grouping Principles 54
    5.2.6 Information Flow 56
    5.2.7 Support Congruence 56
    5.2.8 Design and Human Values 57
    5.2.9 Incompletion 58

5.3 Summary 58

6. RECOMMENDATIONS 59

6.1 Linkages with Other Units 59
6.2 The New Operating Structure 59
6.3 Procedures for Reporting 60
6.4 Unit Rotation/Dedication 60
6.5 Training 60

7. REFERENCES 62

APPENDIX I Nuclear Plant Control Room Communications Questionnaire

APPENDIX II Communications and Systems Principles: A Selective Literature Review

LIST OF DIAGRAMS

Page

DIAGRAM 1 Contour Diagrams of Communication Links 11
DIAGRAM 2 Summary of Communication Links 14
DIAGRAM 3 Contour Diagrams of Task Dependencies 24
DIAGRAM 4 Reporting Relationships Based on Communication Linkages 48

LIST OF FIGURES

FIGURE 1 How Others are Helpful and Unhelpful 19
FIGURE 2 Comments About Other Areas 26
FIGURE 3 Comments About Management and Others 28
FIGURE 4 Comments on New Operating Structure 30
FIGURE 5 Control Room Procedures 32
FIGURE 6 Usefulness of Instruments 35
FIGURE 7 Diagnosing Problems 39
FIGURE 8 Reasons for Miscommunications 41

LIST OF TABLES

TABLE 1 Communication Linkages Identified 9
TABLE 2 Comparisons of Nine Positions 12
TABLE 3 Turnover Duration and Communication Links 15
TABLE 4 Number (Percentage) of Comments Being Helpful 22
TABLE 5 Dependencies on Other Roles 22

COMMUNICATIONS INVOLVING THE CONTROL ROOM OF A NUCLEAR POWER PLANT

1. INTRODUCTION

1.1 Background

The last thirty years in the nuclear power industry have been marked by incidents which illustrate the importance of safe procedures and effective operator performance in the control room. There have been several extremely serious incidents (at Chernobyl in 1986 and at Three Mile Island in 1979) as well as many other less serious events. Human error has often been identified as the key reason for these incidents.

Improved technologies and procedures have offered ways to make the nuclear power industry much safer. Since the 1979 incident at Three Mile Island, emergency reactor shutdowns in the U.S. have been reduced significantly. Designers have improved the nuclear power plant facilities by developing computer operated systems. The goal is to reduce operator error through sophisticated technical designs. New reactors, it is argued, are designed to be more tolerant of human error, giving operators more time to make decisions.

As a result of the Three Mile Island incident, there seemed to be a growing awareness of the operator-plant interface as a potential cause of operator errors. There was a recognition that efficient and effective plant designs are only one consideration. The elements of a nuclear power plant -- including people, hardware, software, and facilities -- must be put together in a way that is operationally efficient and safe. In addition, there is a need to recognize and use resources to ensure that the design responds to other needs, such as managerial coordination, maintenance, adaptation, as well as integrating human and social efficiencies. This is recognized in one of the recommendations of a "Panel on Human Factors Research Needs in Nuclear Regulatory Research."

> ....The operator/maintainer-plant interface is extremely important; but other factors arising from the way in which a plant is organized, staffed, managed, and regulated and the way it interacts with other elements of the industry can also affect human performance, induce human error, and increase the level of risk of a plant.

> The panel firmly believes that research that recognizes a systems approach, in which the "system" is broadly defined, has great potential for delivering results that yield useful recommendations for safety improvements. The systems approach to safety requires multidisciplinary teams and close coordination of programs dealing with different levels and facets of the system.....[1]

1.2 Objective

The objective of the study was to identify and analyze characteristics of voice communication links used in the control room of a nuclear power plant.

1.3 Tasks to be performed

The tasks to be performed were:

(i) to define the command and control structure of the operations component of the plant.

(ii) to define the personnel who interact with the operations component on a periodic basis.

(iii) to define the major others with whom the control room shift crew communicate on a routine basis.

(iv) to define the nature and information requirements of oral and written communication patterns that take place on a routine basis between these groups.

(v) to measure the frequency of these types of oral and written communication links.

(vi) to propose methods for measuring the degree of intelligibility and understanding in communications.

Although this study was an exploratory analysis of one control room, it points out how the results might be verified and implemented.

2. PROCEDURE

We were charged with the general task of understanding the many factors affecting communications within the control room of a nuclear power plant. Two goals dominated the data gathering process:

(i) to provide a perspective on communications which, while employing the conceptual framework of the general systems approach, evolved from the interactions taking place in the specific nuclear power plant being studied, and

(ii) to develop a method of questioning which encouraged factual rather than opinionated comments.

In responding to the first goal, we relied on certain principles of general systems theory. As such, a nuclear power plant is not composed of components whose properties can be examined in isolation, but as a collection of components (including human components) each of whose properties affects and is affected by others. With these principles in mind, we began our research process by observing and questioning certain people who were familiar with the complexity of working within a nuclear power plant.

We were interested in discovering concepts which would describe the human interactions and communications that were taking place, rather than fitting the organization's operations to defined concepts. The interactions in such organizations do not always rely on defined procedures for fixing machines, replacing valves, or turning dials. Rather, many decisions and communications in nuclear power plants are more complex, and are much like a medical doctor who is trying to unravel some of the difficulties a patient is having. A doctor relies on certain tests, background information, other experts, group experience, and a general understanding of the total system.

Our second goal was to develop a line of questions which probed people to identify existing problem areas, past incidents and their outcomes, as well as suggestions they might find useful for improving communications.[2] This line of questions was open-ended and thought-provoking, because it sought to ask people to provide details of specific events rather than opinions or comments which were unfounded. The following is an example of one type of question which was directed at providing this information.

> Can you describe a situation based on your experience of an upset condition in which the root cause was difficult to diagnose? How did you arrive at the correct diagnosis? Who else was involved? (Analogous to a medical doctor correctly diagnosing throat cancer).

Other related questions probed for examples of effective and ineffective communications, procedures, instruments, and skills.

These questions, especially when they are followed with further probes, yield information on what the person did. The questions ask individuals to provide data on incidents or events that people were involved with or observed. A pooling of incidents on various aspects of communication is a review of events that individuals found most important.

The interview schedule was pretested on an operator at the Bruce "A" Nuclear Power Station and pilot tested among officials of the Atomic Energy Control Board. This feedback provided the direction for revising the interview questions and identifying strategies for carrying out the interviews. The interview schedule consisted of 15 general questions. Each question included further probes or sub-questions to provide more detail on the specific area. A copy of the complete schedule is provided in Appendix 1.

Four researchers carried out the interviews at the Bruce "A" Nuclear Power Station between April 23 and 25, 1991. Thirty (30) people on two of the five shift crews were interviewed, in individual sessions lasting approximately one hour. The interviewees represented a cross section of people who worked in the control room area and field of the power plant. Interviews were held with Shift Supervisors - SS (2), Shift Operating Supervisors - SOS (2), Shift Maintenance Supervisors - SMS (4), Authorized Nuclear Operators - ANO (6), Supervising Nuclear Operators - SNO (2), Nuclear Operators - NO (5), Supervised Control Panel Operator - SCPO (1), Fuel Handlers - F-H (4), and Unit 0 operators - U-0 (4). The numbers in brackets show the number of people interviewed from each position.

Because numbers were relatively small, Fuel Handling operators were treated as a single group, even though different positions were represented within the group. Unit 0 was treated in a similar way. Later, when we compare communications between different positions, Fuel Handling and Unit 0 are treated as "positions", though it should be borne in mind that there are different positions within these units whose internal communication patterns may be highly similar to those of the reactor units. The only maintenance personnel interviewed were SMSs. However, respondents sometimes mentioned communications with maintenance in general, without specifying a precise position. For this reason we have grouped maintenance people (MAIN) together.

2.1 Analysis

The first approach to quantifying communication linkages was based on the presence/absence of links between members of each position and every other position. A score of one was given to each position when it was cited by another. These were then summed across all members of the position and divided by the number in that position. So for example, if every one of the six ANOs mentioned the SOS as a communication link, the total would be six, and the average one. Averages could therefore range from zero, indicating that no member of a source position mentioned a particular target position, to one, indicating that every member of a source position mentioned a particular target position.

A sorting or content analysis process was used as a way of ordering or categorizing the open-ended questionnaire data. This is a process of categorizing or content analyzing the narrative responses to develop a list of common categories. The statements generated from the interviews are first categorized in terms of the general content areas, recognizing the intent and meaning of the individual's statements.

Decisions on categorizing interview statements were qualitative. The process was one of trying to understand how various statements or themes were related. We were not limited by a predetermined number of categories, but simply arranged and labelled various interview statements into general categories with common themes. In some cases, we later combined categories and were able to check the consistency of categories' definitions.[3]

The figures in this report represent a summary of the comments made within a specific category. In most cases the figures summarize the number of individuals who provided comments that fell into a category. Individuals could not be included more than once in each specific category, however, an individual could be counted more than once if he or she contributed comments falling into different categories. In other cases, in order to increase the information available, all comments were categorized. A concern when this is done is that the results could be biased by a few individuals making a large number of comments. However, in cases where we have used all the comments there was a high correlation between the number of people making comments in categories and the number of comments made. In other words, the same impression of the salience of response categories resulted from using all comments as would have resulted from the number of people making comments.

3. RESULTS - I

The results are presented within two major sub-sections describing:

(i) the key roles and interactions, and

(ii) how these key roles communicate to carry out certain tasks or functions.

The findings in each sub-section are interrelated, and illustrate general interactions before describing how they can be understood within certain common tasks.

3.1 The Key Roles and Interactions in Control Room Communications

3.1.1 A Typical Shift in the Control Room

This section provides a description of a "typical" shift, compiled from the comments made by all of the interviewees. The purpose of the section is to provide the reader with a qualitative overview of control room communication patterns, which will provide a context for interpreting the more detailed results that follow.

In describing a typical shift, we try to give a "picture" of the main communication links involving the control room in the context of the ongoing operations of a unit. The description is made from the point of view of the Authorized Nuclear Operator (ANO) position, but it incorporates information provided by other positions including Shift Operating Supervisor (SOS), Supervising Nuclear Operator (SNO), Nuclear Operator (NO), Shift Supervisor (SS), Shift Maintenance Supervisor (SMS), Supervised Control Panel Operator (SCPO), Unit 0, and Fuel Handling.

> (a) Start of Shift: The shift begins with "turnover" where the incoming ANO on a unit relieves the outgoing ANO. The turnover takes place face-to-face, and typically lasts about 15-20 minutes, though it may take from 30 to 60 minutes if there is an outage or other atypical condition.
>
> Turnover involves a review of "unit status", including discussion of unit conditions, major ongoing work, "quirks" specific to the unit, and any equipment failures or abnormal incidents. The unit summary sheet and chronological log is reviewed, as well as any outstanding work permits. Turnover concludes with a "panel walk", sign-off and sign-on.
>
> Following turnover, the ANO is immediately involved in a number of communication activities, all face-to-face. The SNO and NOs come up from the field, following their turnovers, and congregate at their unit in the control room. The ANO and SNO exchange turnover information and check for inconsistencies or missing information. The SOS will come around to the unit, following his daily planning meeting, and will check on unit status and turnover consistency, and discuss plans for the shift. Planning involves prioritizing and scheduling jobs, taking into account scheduled maintenance work and whether isolation is required. The ANO will talk briefly with the Shift Maintenance Supervisors about jobs that Maintenance want to do and jobs that the Unit want Maintenance to do. This usually takes place face to face and sometimes by phone.

Following this the ANO may be involved in assigning jobs to NOs, though this is officially a function of the SNO. The degree to which different ANOs involve themselves in this seems to vary considerably. However, the ANO will typically be involved in providing NOs with specific technical details about tasks, for example System Safety Test (SST) valving.

During the early part of a shift the ANO will converse with the Unit 0 First Operator about the Unit's manoeuvrability up or down, and receive information about plant status. Fuel Handling may check with him about fuelling needs/plans. The ANO will also have a brief conversation with his SCPO to schedule lunch.

In the early part of the shift (the first 2 hours) the ANO will complete the panel check sheet, run three panel SSTs and start running field SSTs. He will review the log of previous shift(s) and operator turnover sheets. He will also obtain the Unit Status print-out from the computer and review its summary of trends, steam pressure, unit power, current alarms, etc.At this point, Trades start to filter in and the ANO will begin to issue work permits.

(b) Middle of Shift: During the shift, the ANO is in continuous contact with the field, either face-to-face when the SNO, NOs or Trades come to the control room, and frequently by pager and phone, or radio. These communications involve giving information on maintenance to the SNO, getting information on field status from the SNO and NOs, and providing information and instructions to NOs. Co-ordination may be required during System Safety Tests, when the ANO may instruct the field to carry out certain operations, at the same time observing effects on the control panel. (Four or five SSTs may be conducted during a shift.) Communication in this case may be by radio, though difficulties arise because of numerous "dead zones" in the plant, even if the NO can find a radio that works. For this reason telephone is often used, though this may mean that the NO has to leave the actual site of the operation in order to talk to the Control Room. This may make it less easy for ANOs to double check that the NO is at the proper location, for example by asking the colour of wiring immediately above a valve, or carrying out some other check that is specific to that equipment or location.

In the control room, the ANO provides SMSs and Trades with authorization for work they want to do and, when necessary, obtains authorization from the SOS and SS. He will talk with Unit 0 several times per shift regarding terminal voltage requirements, and with Fuel Handling every other shift during fuelling. The SOS will routinely drop by during the shift to find out how his jobs are progressing, while the ANO will contact the SOS if a System Safety Test should fail. The ANO may also phone the Technical Unit with questions or, if a

Deficiency Report has been filed, the Technical Unit may call for trends or the history of the problem. The computer technicians may come by to carry out their panel checks.

At some point, the ANO will go for lunch, handing over the unit to the SCPO. This involves two "turnovers" -- ANO to SCPO before lunch and SCPO to ANO after lunch. (Similar lunch-break turnovers presumably take place on Unit 0 and Fuel Handling, and it seems probable that mid-shift turnovers will take place routinely for various reasons. Nevertheless, of 13 interviewees who are likely to be involved in this type of turnover -- ANO's, SCPO, Unit 0 and Fuel Handling First Operators and MPOs -- only one mentioned it in his listing of communication linkages.)

In the event that some problem arises on the unit, the ANO may call on other ANOs for help or advice. The SOS and SS may also become involved in problem solving.Aside from these direct communication activities, the ANO (i) monitors the Unit, including watching the panel, making minor dial adjustments and resetting alarm levels, (ii) reviews work plans, prepares work protection packages and completes paperwork on SSTs, and (iii) logs power changes, equipment operations and permits.

(c) End of Shift: The end of the shift involves "shift wind-down" and turnover. Wind-down involves the completion of jobs, the closing of work permits and the preparation of summaries and reports for turnover.

During this part of the shift, the ANO typically meets with his SNO and SOS, and may communicate with the SS, NOs,or SMSs. Trades may also phone in.

The SNO comes up from the field to discuss his work report, the status of jobs and any Deficiency Reports. The ANO incorporates this into his shift summary, which he discusses with the SOS for his turnover. He completes the log and then turns over the Unit to his replacement. Turnover would normally take 15 to 20 minutes, though may require longer if the incoming ANO is returning after 10 days off, or if there are problems with the Unit.

3.1.2 Quantitative Analysis of Communication Linkages

The data used for identifying communication linkages came from responses to Sections A, B and C of the interview schedule. The questions asked interviewees to identify, for the start, middle and end of a shift, the major communication linkages they have with other positions. For each link they were asked to give the mode, the frequency and the reasons for the communication. No restriction was placed on the number of linkages they might identify or the positions of those linkages within (or outside) the plant.

The number of communication linkages is a summary of the number of times individuals in a position identified others positions. To provide an overall measure, entries were summed over the start, middle and end of shift, and divided by three, to give the mean number of members of a position citing another position as a link on all three phases of a shift. Values could range from zero to one. A value of zero indicates that no member of a position cited the other position in any phase of a shift, while a value of one indicates that every member of a position cited the other position on all three phases of the shift. These results are shown in Table 1.

Table 1
Communication Linkages Identified

		Other Positions								
		ANO	SNO	NO	SOS	SS	SCPO	Maint	F-H	U-0
Source	ANO	.11	1	.78	.94	.55	.39	.78	.22	.11
	SNO	1	0	1	.83	0	0	.50	0	0
	NO	.73	.73	.47	.13	.07	.07	.13	0	0
	SOS	1	.50	.17	0	.67	0	.67	.17	.50
	SS	.83	.17	.17	1	0	0	1	0	0
	SCPO	1	.67	.67	0	0	0	.33	0	.33
	Maint	.58	0	0	.33	.67	0	.83	0	.08
	F-H	.50	0	0	.42	.08	0	0	.47	.17
	U-0	.42	0	0	.50	.33	0	.25	0	.70

The rows of the table show what members of specific positions reported about communications with other positions. The columns show what other positions reported about members of a specific position.

Looking at the first row, for example, the second, third and fourth columns show that ANOs reported frequent links with the SNO, NO, and SOS positions, respectively. Looking at the first column, the second, third and fourth rows show that SNOs, NOs and SOSs reported frequent links with the ANO position. So for this particular case, whether we look at the ANO position as a source or a target, a similar picture emerges.

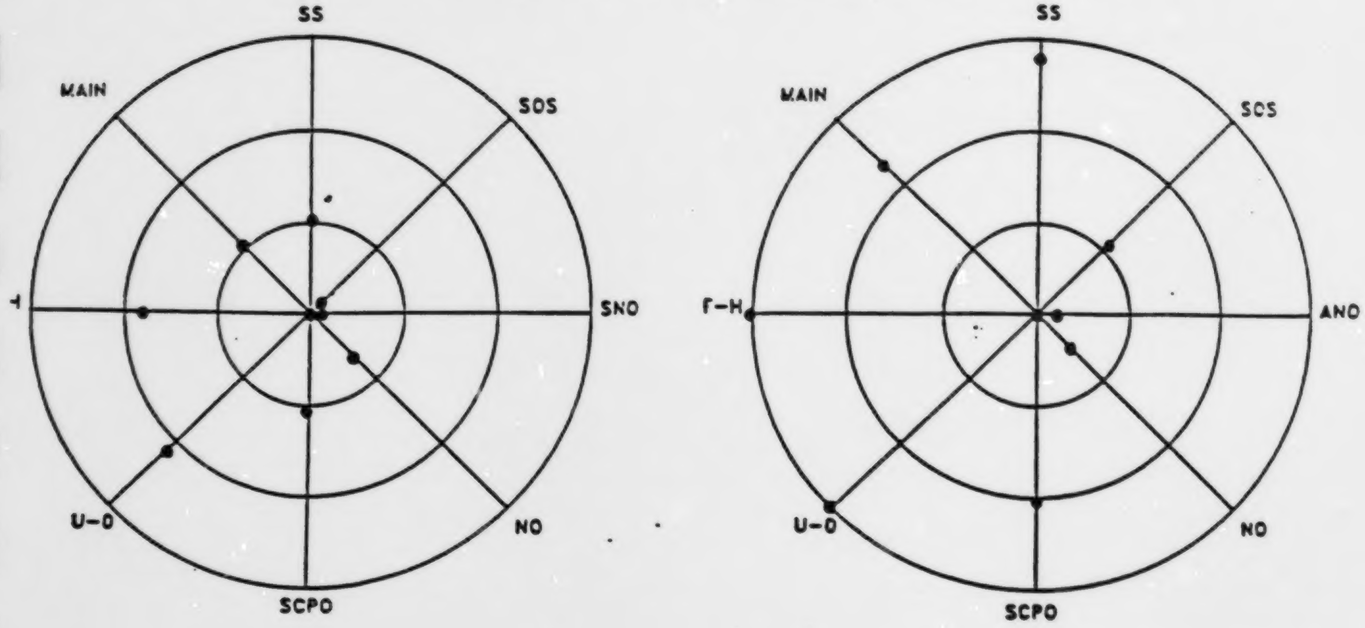
The extent of this type of symmetry provides an indication of the internal consistency of the data, and one overall measure of symmetry is the correlation between the values in Table 1 reported from the source perspective with the corresponding values reported from the target. That is, for each of the 81 cells of the matrix the correlation between Cell(i,j) and Cell(j,i) is found. The resulting correlation between source and target reports of communication links was r = 0.70, indicating a relatively high level of agreement for data of this kind.

Of course, some of the asymmetries in the data may represent quite legitimate and meaningful differences in perspective. A good example of this appears in the results for the SCPO position. Looking at Row 6 of Table 1, it may be seen that the SCPO reported communication links with the ANO, SNO, NO, Maintenance and Unit 0. Looking down Column 6 of the Table, it can be seen that only the ANO and NO positions mentioned links with the SCPO position. An overall impression of the degree of discrepancy between source and target perspectives can be obtained by comparing the row and column totals. For the SCPO position these were 3.00 and 0.46, respectively, indicating a high degree of discrepancy between what the SCPO position reported about others and what others reported about the SCPO position. The reason for the discrepancy is probably due to differences not in the actual presence of linkages but in their perceived relative importance. Other positions probably do communicate with the SCPO on a regular basis but, relative to other communication linkages, the link with the SCPO is not particularly salient to them. (This is consistent with other information about the nature of the SCPO position, which will be discussed at a later point.) When the SCPO data was excluded, the correlation between source and target values increased to 0.79.

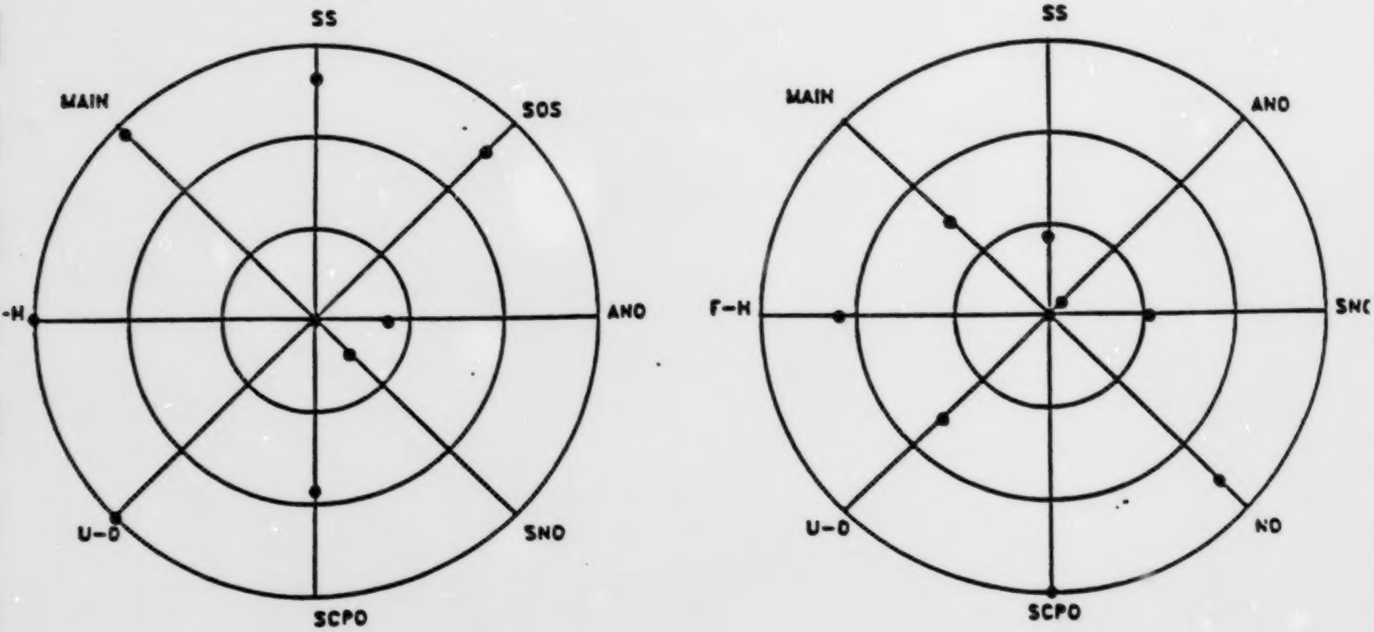
One way to visually summarize the information in Table 1 is with "contour diagrams" showing the proximity between different positions. To do so, the "strength" of communication links between any two positions was found by adding the values from corresponding cells above and below the main diagonal of Table 1. Thus, the total for the ANO/SOS relationship was found by adding the value of .94 from Cell(1,4) to the value of 1 from Cell(4,1). The "distance" between the positions was then found by subtracting the result from the maximum possible value of two. For each position a contour diagram was then constructed with that position in the centre and the other positions placed on one of the eight major axes of the compass, at a distance determined in the above manner. In such a diagram, points that are closest have the highest degree of communication linkage, while points falling on the outer contour have no communication link at all with the focal point. For purposes of illustration the diagrams for four positions (SOS, ANO, SNO and NO) are reproduced below.

In Diagram 1 the position in larger letters at the bottom of each of the four charts shows the name of the focal position for that diagram. The name at the end of each axis indicates the position portrayed along that axis. The distance from the centre of the point on the axis reflects the closeness of contact between that position and the focal position. For ease of comparison, concentric circles have been drawn at one-third and two-thirds of the distance from centre to circumference.

Diagram 1
Contour Diagrams of Communication Links



ANO SNO



NO SOS

Looking first at the ANO diagram it can be seen that ANOs are in very close contact with both their SOS and their SNO. They are also in relatively close contact with the NOs, SS, Maintenance and SCPO, and have some contact with Fuel Handling and Unit 0. Looking next at the SOS, he is in closest contact with the ANOs and SS, followed by SNOs, Maintenance and Unit 0. He is also in contact with Fuel Handling but has no reported contact with SCPOs.

An overall impression of the closeness and extent of a position's contacts with others can be obtained by looking at the number of points falling within each of the concentric circles of a diagram. For example, if we take the inner circle as indicating "very close contact", then the ANO position is in very close contact with three other positions, while the SOS, SNO and NO positions are each in very close contact with two other positions. If we take the middle circle as indicating "close contact", then the ANO position is in close or very close contact with seven other positions, the SOS with six, and the SNO and NO positions with three. Finally, if we take the outermost circle as the boundary of "some contact", then the ANO has at least some contact with all eight other positions, the SOS with seven, the SNO and NO with six. Table 2 shows the results of these comparisons for all nine positions. Note that the numbers are cumulative across the rows of the table (a position in very close contact is counted also as being in close contact and some contact).

Table 2
Comparisons of Nine Positions

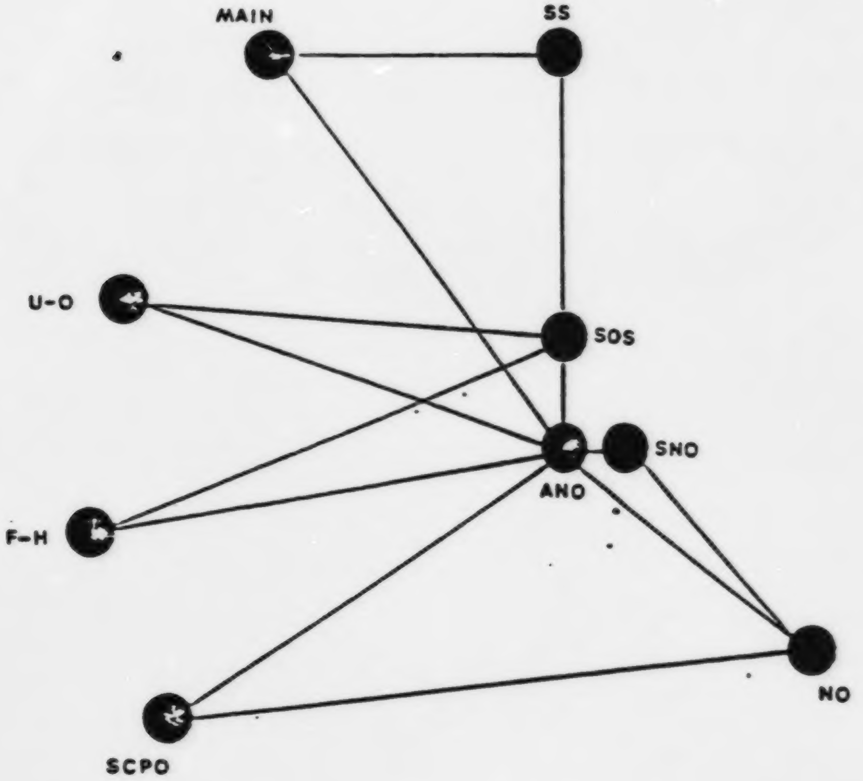
Number of others who are in: Position	Very Close contact	Close contact	Some contact
ANO	3	7	8
SNO	2	3	6
NO	2	3	6
SOS	2	6	7
SS	2	3	5
SCPO	1	2	5
Maint	1	4	4
F-H	0	1	2
U-0	0	1	2

Approximate as these measures are, they show some consistency. For example, the ANO has the greatest number of contacts at all levels of proximity, followed by the SOS, while F-H and U-0 have least contact with other positions. Maintenance shows a special characteristic, in that although there are only four reported contacts, all four of them are close or very close. The ANO and SOS positions show a similar pattern, in that almost all of their reported contacts fall within the present criteria of close or very close. The SS is the only other position where a majority of the total contacts are close or very close.

To get a single, simplified picture of the whole communication network, the two strongest linkages only were plotted for each position. The results are shown in Diagram 2 below. Again the relative strength of linkage is shown by relative proximity, but in this case the distances are in rank order only and not proportional to the strength of the linkage.

This overall picture reinforces the impression given by the previous analyses, of the centrality of the ANO position within the communication network. It has seven out of a possible eight linkages, which means that seven of the eight other positions cited ANOs among their two strongest linkages. The diagram also suggests the presence of two major subgroups, one involving the ANO and field operators (SNO and NO), the other involving the ANO and the management team (SS, SOS and SMS). The diagram suggests that the ANO position is a major link in communications between these groups. The next most central position in the network is that of SOS, with a total of four linkages.

Diagram 2
Summary of Main Communication Links


MAIN
SS
U-O
SOS
SNO
ANO
F-H
NO
SCPO

3.1.3 Amount of Communication Based on Other Estimates

As well as giving information about communication linkages, respondents gave estimates of the frequency and duration of certain communication activities. With respect to frequencies, respondents often used terms like "ongoing" or "continuous" rather than providing a numerical estimate. When numbers were provided, the variability within positions was enormous. For example, one ANO estimated two to three phone calls to NOs per shift. Another estimated 40. Similar variability appeared within individual estimates. For example, one NO estimated three to 50 contacts with the ANO per shift, depending on circumstances. These were by no means isolated cases, and it appears that frequency of communications does vary a great deal depending on conditions.

With respect to duration, one communication activity where individuals were usually able to provide an estimate of duration was turnover. The results for this are shown below, together with overall communication linkages.

Table 3
Turnover Duration and Communication Links

Position	Mean	Range	Communication Links
SOS	26	15 to 30	7.83
ANO	25	15 to 60	11.05
SMS	18	10 to 25	6.98
U-0	6	10 to 30	4.09
SS	15	10 to 20	5.54
SNO	11	10 to 15	6.40
F-H	9	5 to 15	2.50
NO	7	1 to 15	5.59
SCPO	5	4 to 5	3.46

It can be seen that the positions with the longest turnovers (SOS and ANO) also had the largest number of communication links, and across all nine positions the correlation between turnover duration and communication links is 0.78. This may reflect a relationship between communication activity and amount of information processing within positions. Turnover information is passed up through a Unit's chain of command, in that NOs communicate with their SNO for his turnover, the SNO in turn communicates with the ANO for his turnover, and the ANO passes on information to the SOS. Information passed on at turnover also comes from other sources. Almost anyone who has been working in the field may report to the ANO, including Trades, Maintenance and NOs. Unit 0 provides information to the SOS, as may SNOs. It is reasonable therefore to suppose that positions that are involved to a greater extent in communication will also require longer turnover periods to pass on the information that has been communicated to them.

3.1.4 Communication with Other Components in the Plant

Respondents mentioned other, less frequent, linkages with elements beyond the boundary of the operations component.

The most frequently mentioned of these was the Technical Unit (cited by four ANOs, 3 F-H, one SMS and one SNO), followed by the Chemical Labs (cited by two NOs and one SS). Others included Trades, Stores, the System Control Centre and Plant Management (each cited twice). The most striking aspect of these results is how weak the linkages appear to be between the operations component and other parts of the organization. This is consistent with other information, discussed later, which suggest that there is a strong sense within the operations component of being isolated from the rest of the organization.

4. RESULTS - II

Our second set of results suggests that people use different types of information when they communicate on a range of organizational tasks. Communications concerned with directing and assuring that decisions are carried out efficiently and safely are called productive functions. Adaptive functions are concerned with responding to a range of difficult and complex decisions which are generated by the environment or by internal events. Communications concerned with coordination are necessary for the overall functions of management and control; those concerned with repairing and helping are labelled maintenance functions. Underlying these technical communications are a number of interactions related to interests of participants and their unique ways of working. The second set of results illustrates how operators carry out these essential functions.[4]

4.1 Requirement 1 -- Coordination and Dependence on Others

4.1.1 Dependencies within the Production Unit

Given the need to meet production requirements while maintaining high safety standards, together with the technical complexity of the operation, very high degrees of coordination are required within the production function of this organization. Within each shift the SS and SOS, the SMSs and the Units themselves may have certain jobs to accomplish, and activities have to be organized and prioritized to accommodate them. Unforeseen circumstances may arise at any time which necessitate a reorganization of priorities and a rescheduling of activities. The ANOs may be involved with SNOs and NOs on tasks that involve ongoing coordination of control room and field operations. Similar coordination may be required between operational and technical personnel in the field. Fuel handling has to be conducted within production and maintenance constraints, while Unit 0 has to coordinate the other Units' outputs to meet plant production requirements. A high level of coordination must also be achieved across shift changes, where it is accomplished by the one-to-one overlapping of each person.

Where coordination requirements are as high as this, we would expect to find not only a great deal of communication but also a high degree of dependency between different positions. By "dependency" we mean that task performance in one position may be directly affected by the actions (or inactions) of another position. Furthermore, the network of task dependencies should reflect the main channels of communication. If this were not the case, and a dependency existed where there was no communication channel to adjust or alter activities, problems of coordination are likely to arise.

At first sight, a relationship between communication and task dependency might appear to be typical of any organization, but this is not the case. In bureaucracies, for example, the operations of the production function may be so highly routinized, and so heavily insulated from unanticipated inputs, that very low levels of dependency exist. So long as certain minimum production standards are met, task performance in one position may have almost no impact on performance at connected positions.[5]

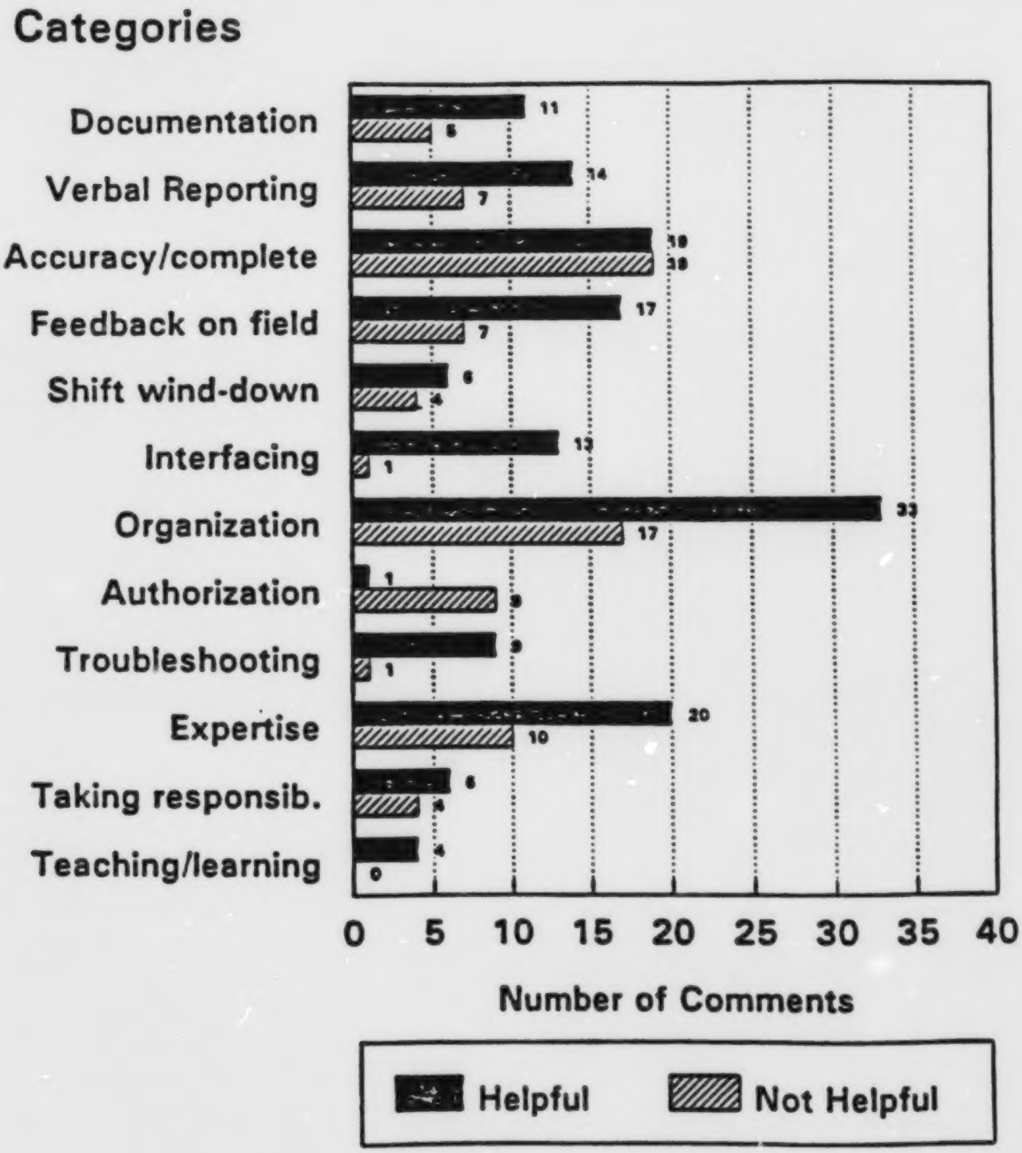
In the present case we obtained information about dependencies in Section D of the interview schedule, which asked interviewees for specific examples of things that individuals or groups did that were helpful (and not so helpful) to them in doing their job. For consistency, we will refer to the interviewee as the "source", and the individual or group cited as the "target". The question therefore provided information that linked a source and target through an action that had a valence, positive or negative. This information was analyzed in several ways. First, it was analyzed qualitatively by categorizing the nature of the valenced activities themselves. Then it was analyzed quantitatively in terms of the number of dependencies between source and target positions, in a manner parallel to that used with the communication links in the previous chapter. Finally, the resulting network of dependencies was compared to the network of communications. It is important to note that a relationship of this kind was not forced by the question. Although people were asked to respond in the context of the communication links previously identified, it was still quite possible that more dependencies might be attributed to people they communicated less frequently with, and vice versa. In other words, it was possible for a negative relationship, or no relationship at all, to occur between the network of communications and the network of task dependencies. Observations made in highly routinized work environments have in fact found that there may be no relationship between these variables.[6]

The interviewees provided a total of 264 examples of things that others within the production unit could do that were helpful, or not so helpful, in doing their jobs. The majority of the examples (63%) were positive. We were able to classify 237 of the comments into 12 categories of activity that were clearly job-related. Of the remaining 27 examples, 11 were concerned with social or personality issues (eg. "we get along well", "sometimes hard to deal with") while the remaining 16 were of a miscellaneous nature.

The 12 categories illustrated in Figure 1 can be grouped into three broader categories. The first of these was concerned with providing information, the second with the organization of manpower, jobs, priorities, etc., and the third with personal ability/expertise.

> (a) Positive Comments about Information Providing: A number of comments were concerned specifically with written communications/documentation (11 comments, made by 11 respondents), where people appreciated receiving well-written summaries and procedures that were well-marked. Other positive comments specifically concerned verbal reporting or oral communications (14 comments, made by 10 respondents), and included openness to questions, summarizing concisely, and providing background information. Most of the comments in the information category were about the accuracy and completeness of information (19 comments, made by 14 respondents), where people appreciated the story being right and attention being paid to detail. Feedback on field activity, such as providing information on the status of jobs, was also valued (17 comments made by 15 respondents).

Figure 1
How Others are Helpful and Unhelpful



(b) Not-so-positive Comments about Information Providing:
There were a number of negative comments about documentation, including inconsistent turnover reports and failure to mark the place on procedures(five comments, made by five respondents). Verbal reporting also received a number of negative mentions, including unnecessary verbosity and asking unimportant questions (seven comments, made by six respondents). As with the positive comments, most of the negative comments were about accuracy and completeness, where many of the concerns were about information not being passed on (19 comments, made by 13 respondents). Feedback on field activities was mentioned seven times, by six respondents, in a negative context, usually for not being provided.

Comments about information providing were equally distributed across all of the positions, as was the ratio of positive to negative instances, which is consistent with the strong emphasis placed on accuracy of communication and information within the operations component as a whole.

(c) Positive Comments about Organization: The next largest main category was concerned with general organization. A number of positive comments were made about shift wind-down, where people appreciated the previous shift handing on the unit running "slow", and with projects completed (six comments, from six respondents). Providing an interface with others received 13 mentions (from 10 respondents), and included instances like chasing down requests with maintenance or providing an interface with other units. Most of the positive comments in this category were about the organization of priorities, jobs, etc. (33 comments, made by 21 respondents), and included planning ahead, linking plans to unit priorities and giving advance notice of upcoming work. The last subcategory was concerned with authorization/lines of authority, which received only one, somewhat back-handed, positive comment, about not by-passing proper channels.

(d) Not-so-positive Comments about Organization: There were four negative comments (made by four respondents) concerning shift wind-down, including being handed over a unit with a mess of problems going on, or being assigned jobs late in a shift. Interfacing received only one negative mention, about being forced to provide an interface because of other's failures to respond to requests. Most of the negative comments in this category, like the positive comments, were about the organization of priorities and jobs, and included failure to set priorities and changing plans without notice (17 comments, made by 15 respondents). The last subcategory, authorization/lines of authority, received nine negative comments (made by five respondents). These included signing work authorizations without proper authority, too many people telling work groups what to do and by-passing the chain of command.

Unlike concerns with information, comments about organization were not equally distributed across the operations component, either in terms of source or of target. Three-quarters of all the comments came from two positions, while two-thirds of the comments were directed at two positions. The main sources of comments were ANOs, who made 46%, and NOs, who made 28%, roughly twice as many as expected if comments were equally distributed across sources. The main targets of comments were SNOs, receiving 36% and ANOs, receiving 30%. These patterns suggest again the close interconnection of the ANO, SNO and NO roles that was observed in the analysis of communication links. That the pattern should emerge again in the context of comments about organization may be an effect of the new operating structure. This is discussed in more detail at a later point.

(e) Positive Comments about Personal Ability/Expertise: There were nine positive comments about troubleshooting, usually involving spotting or correcting a problem in the field (made by seven respondents). Twenty positive comments were about expertise, and included providing help, good ideas, technical advice (made by 11 respondents). Other positive comments were about taking responsibility, for example, people solving their own problems and taking care of their safety (six comments, from six respondents), and teaching/learning, such as providing learning opportunities (four comments, made by three respondents).

(f) Negative Comments about Personal Ability/Expertise: Almost all of the negative comments in this category concerned expertise, and were mainly about lack of training or experience or skill (10 comments, made by four respondents).

Unlike the comments about organization, the comments in this category showed no tendency to be associated with any particular positions.

Of the 237 comments that were classified, 65% were positive, 35% negative. Most comments (42%) fell into the broad category of "providing information", with 35% concerned with "organization" and 23% with "personal ability/expertise". The breakdown of the major categories into positive and negative comments is shown in Table 4.

Table 4
Number (percentage) of Comments of Being Helpful

Category	Positive	Negative
I Providing information	61 (26%)	38 (16%)
II Organization	53 (22%)	31 (13%)
III Personal ability/expertise	39 (17%)	15 (6%)

About one-third of the comments in the largest category -- providing information -- were concerned with turnover. Of the turnover comments, 21 were positive and 11 negative. The positive comments refer to documents (seven), verbal reporting (seven), accuracy (five), and feedback (two). The negative comments pinpoint some difficulties with documents (five), inadequacies in verbal reporting (seven), and inaccuracies (two).

4.1.2 Patterns of Dependency Linkages

To allow direct comparison with the communications data, dependency linkages were counted in a similar way to communication linkages. For each individual in a position other positions cited as a source of influence, positive or negative, were given a score of one. These were then summed across all members of the position and divided by the number in that position. As with the communication data, averages could therefore range from zero, indicating that no member of a source position mentioned a particular target position, to one, indicating that every member of a source position mentioned a particular target position. The results are shown in Table 5.

Table 5
Dependencies on Other Roles

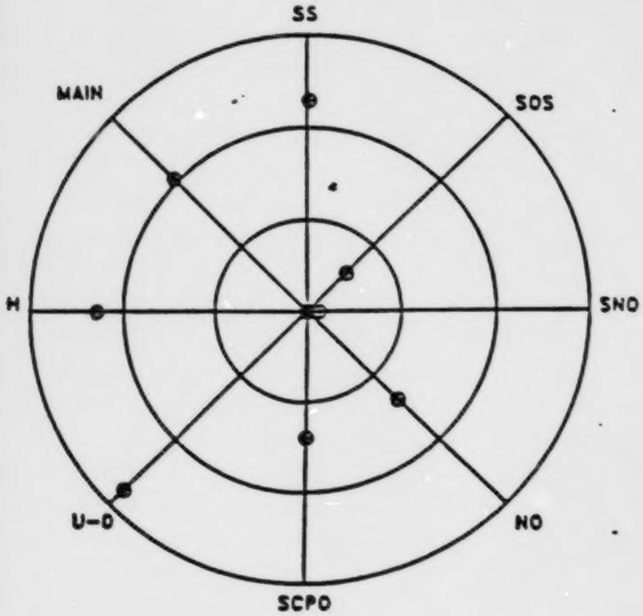
		Other Positions								
		ANO	**SNO**	**NO**	**SOS**	**SS**	**SCPO**	**Main**	**F-H**	**U-0**
Source	**ANO**	.33	1	.33	.83	0	.17	.17	0	0
	SNO	1	0	1	.5	0	0	0	0	0
	NO	.8	1	.8	.2	0	0	0	0	0
	SOS	1	.50	0	0	1	0	0	0	0
	SS	.5	0	0	.5	.5	0	.5	0	0
	SCPO	1	1	1	0	1	0	0	0	0
	Main	.25	0	.25	0	.5	0	.75	0	0
	F-H	.5	0	0	0	.25	0	0	.75	0
	U-0	.25	0	0	0	0	0	.25	0	1

The rows of the table show what members of specific positions reported about influence from other positions. The columns show what other positions reported about members of a specific position. The correlation (between source and target) was $r = 0.49$. As with the communication data, the greatest discrepancy between source and target perspectives occurred with the SCPO position. Row 6 of the table shows that the SCPO reported the ANO, SNO, NO, and SS as sources of influence on his task performance. Column 6 of the table, however, shows that only one ANO and no member of any other position cited the SCPO position as a source of influence. When the SCPO data is excluded, the correlation between source and target values increases to 0.76, indicating that there is a relatively high correspondence between how different positions view the dependencies that exist between them.

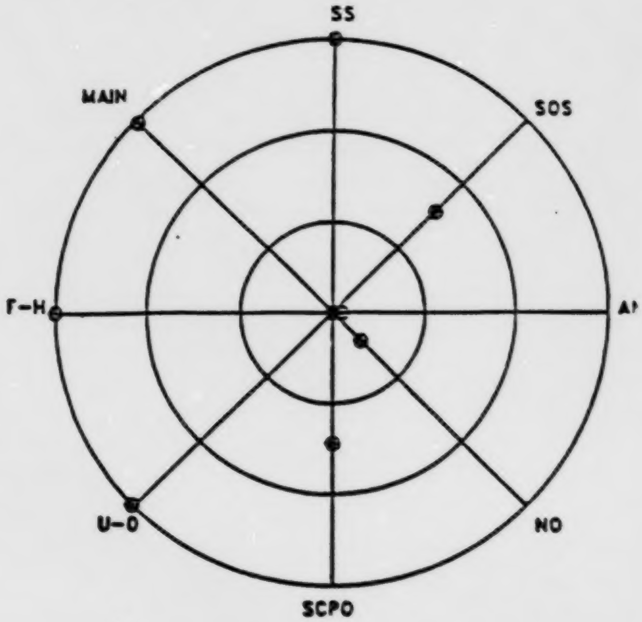
(a) Contour Diagrams: Some of the data in Table 5 is presented in Diagram 3 in the form of contour diagrams. The contour diagrams were constructed by obtaining "proximities" between positions based on their reported dependencies in a manner parallel to that used for summarizing the communication links. As with the communication contour diagrams, the resulting diagrams represent maximal dependency by maximum proximity, where points touch, while positions having no dependency relationship with the focal position fall on the periphery. The results are shown below for the ANO, SNO, NO and SOS positions.

It was suggested previously that where coordination needs are great, the pattern of communication linkages between positions should reflect the pattern of dependencies between them, otherwise coordination problems may arise. In the present case, there is a considerable degree of overlap between the communication links shown in Diagram 1 and the dependencies shown in Diagram 3. For the ANO position, the two closest positions (SOS and SNO) and the two most distant positions (F-H and U-0) are the same as in the previous diagram. There is a similar consistency for the SOS, SNO and NO diagrams. For these positions, the correlations between the proximity values from Diagram 1 and those from Diagram 3 are high, ranging from .85 to .96. A more complete summary measure of the similarity between communication links and patterns of dependency is the correlation between the corresponding values in Tables 1 and 5, which was 0.73. To a relatively high degree, therefore, the network of communication links is reflected in the network of task dependencies.

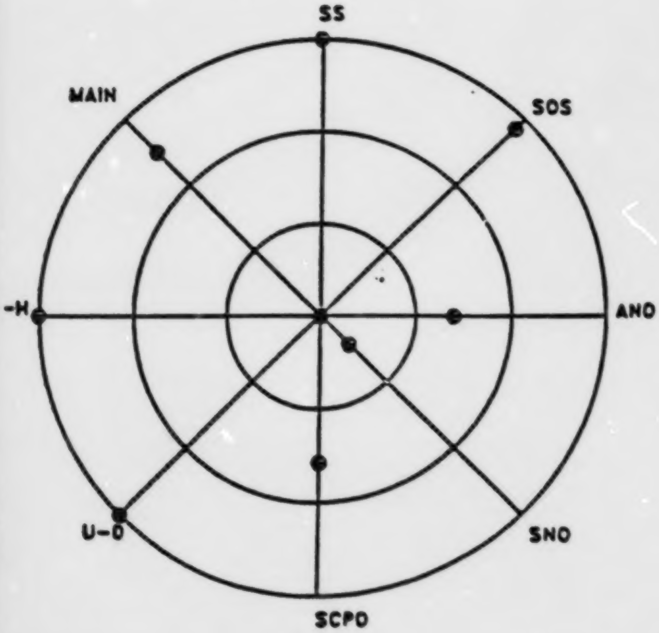
Diagram 3
Contour Diagrams of Task Dependencies



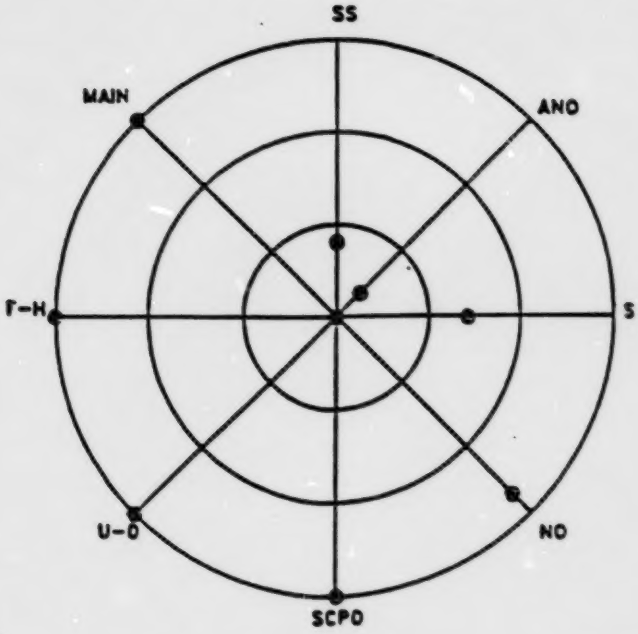
ANO



SNO



NO



SOS

4.1.3 Dependencies of the Production Unit on Other Components of the Organization/Industry

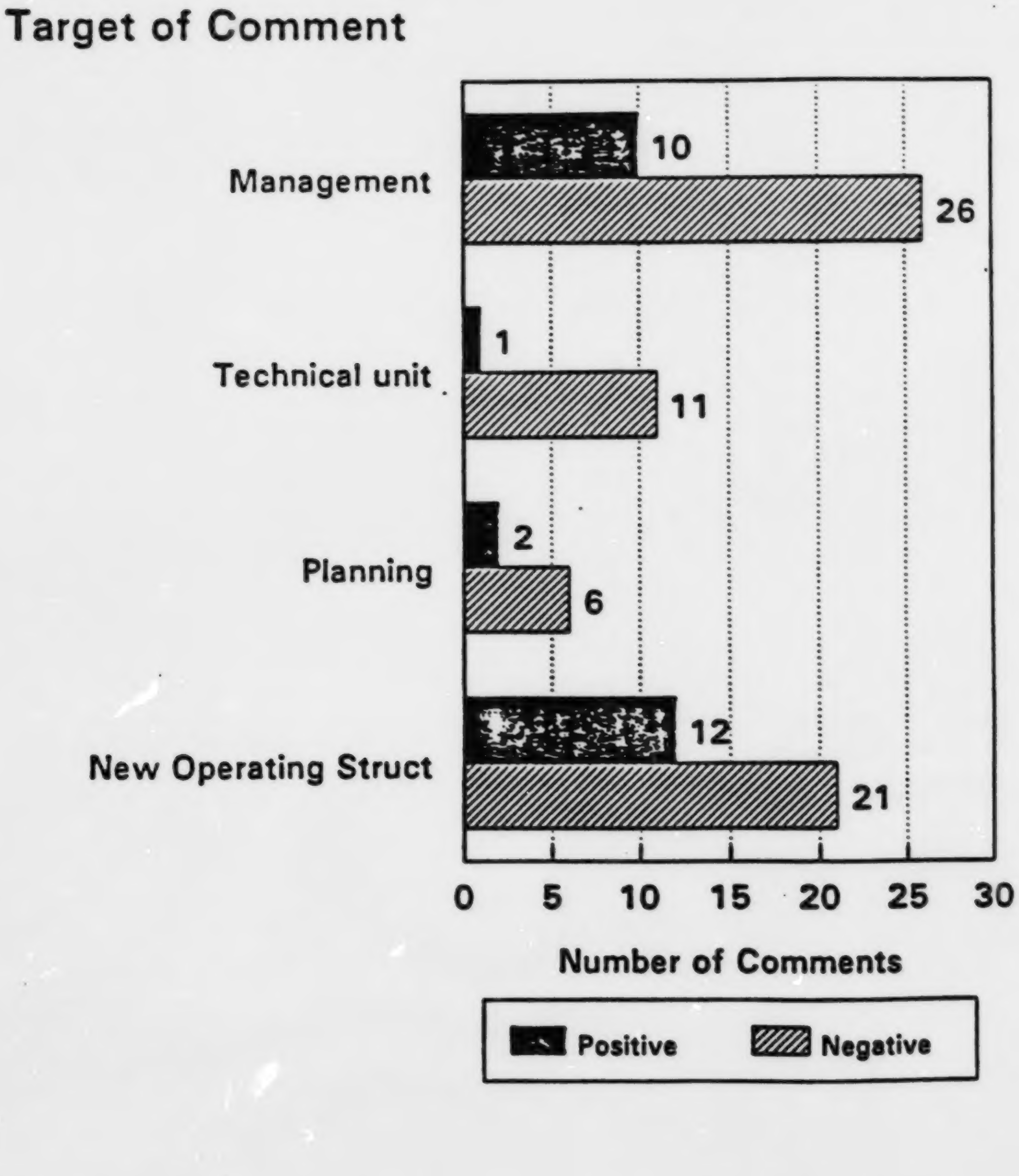
The main interview questions on work relationships asked respondents about work relationships with people and groups whom they had identified as part of their communication network. In addition, we asked follow-up questions about relationships with people or groups that respondents had not specified as communication links. These subsidiary questions were worded as follows.

> In addition to the working relationships you have already mentioned I would like to ask you about relationships with other people or groups who can affect your work but who you don't communicate with on a regular basis. They might be people working in other components in the plant, or they could be outside the plant.
>
> Could you give some specific examples of things that such individuals or groups do that are helpful to you in your job?
>
> Could you give some specific examples of things that such individuals or groups do that are not so helpful to you in your job?

This provided information about perceived relationships with elements that were typically outside of the operations component. This section presents those results as they concern other elements within the Bruce "A" plant. Figure 2 provides a breakdown of the results.

A total of 89 comments were made, 25 positive and 64 negative. About two-thirds of the comments concerned other units within the plant (Management, Technical Unit and Planning), while one-third were about the new operating structure. These are discussed separately below.

FIGURE 2
Comments About Other Areas



There were 10 positive and 26 negative comments about Management, one positive and 11 negative about the Technical Unit, and two positive and six negative about Planning. The number of respondents making positive and negative comments about these components were: seven positive and 13 negative for Management; one positive and seven negative for the Technical Unit; two positive and four negative for Planning. The comments about Management, Planning and the Technical Unit were of a similar nature, and were combined for purposes of classification. The majority of the comments (70%) could be described in terms of five categories -- working conditions, size of bureaucracy, communication/contact, realism of decisions/plans, and shifts. The remainder were of a miscellaneous nature including support, supervision, blaming, and technical competence.

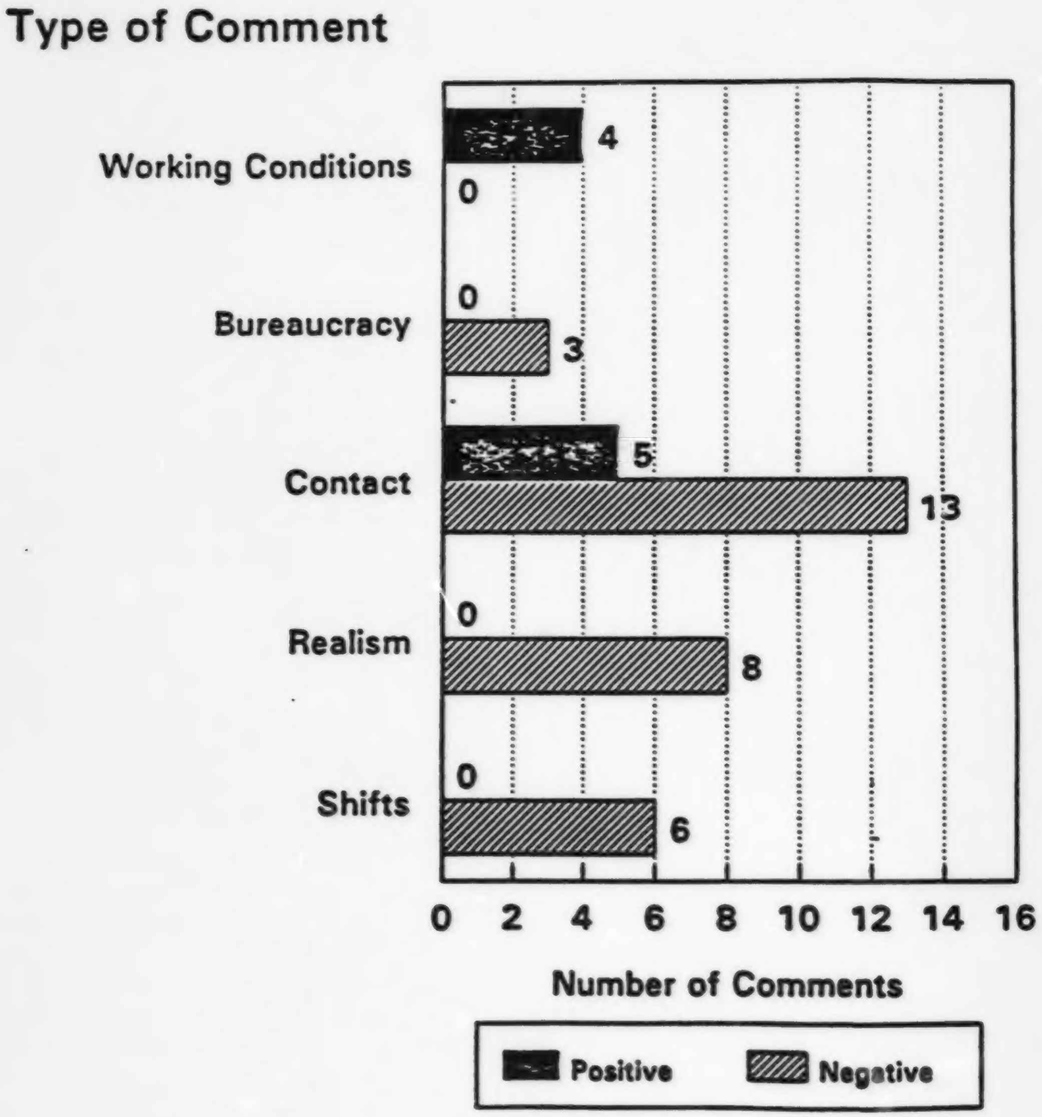
Figure 3 shows the number of positive and negative comments in each of the five main categories.

All of the comments about working conditions were positive, and cited pay, health club and attention to safety. Comments about the bureaucracy were all negative, and cited size and slowness. The largest category concerned communication and contact. Here there were five positive comments, mainly directed towards the usefulness of newsletters. The 13 negative comments were mainly about the lack of information from or communication with management technical components. There were eight comments about the realism of decisions and plans, all negative, and mostly that they don't fit the operational situation. Finally, there were six comments about shift-work, all negative, including comments about management's lack of understanding of shift work, important decisions being made only on day shift, and the lack of say given to shift-workers.

It can be seen from the nature of the last three categories that they are all in some way concerned with other components' degree of contact with and understanding of the operational component. Almost all of these comments were negative, and suggest a fairly prevalent feeling within the operations component of isolation from the rest of the plant. This is consistent with the almost complete absence of linkages which emerged in response to the communications questions.

Figure 3

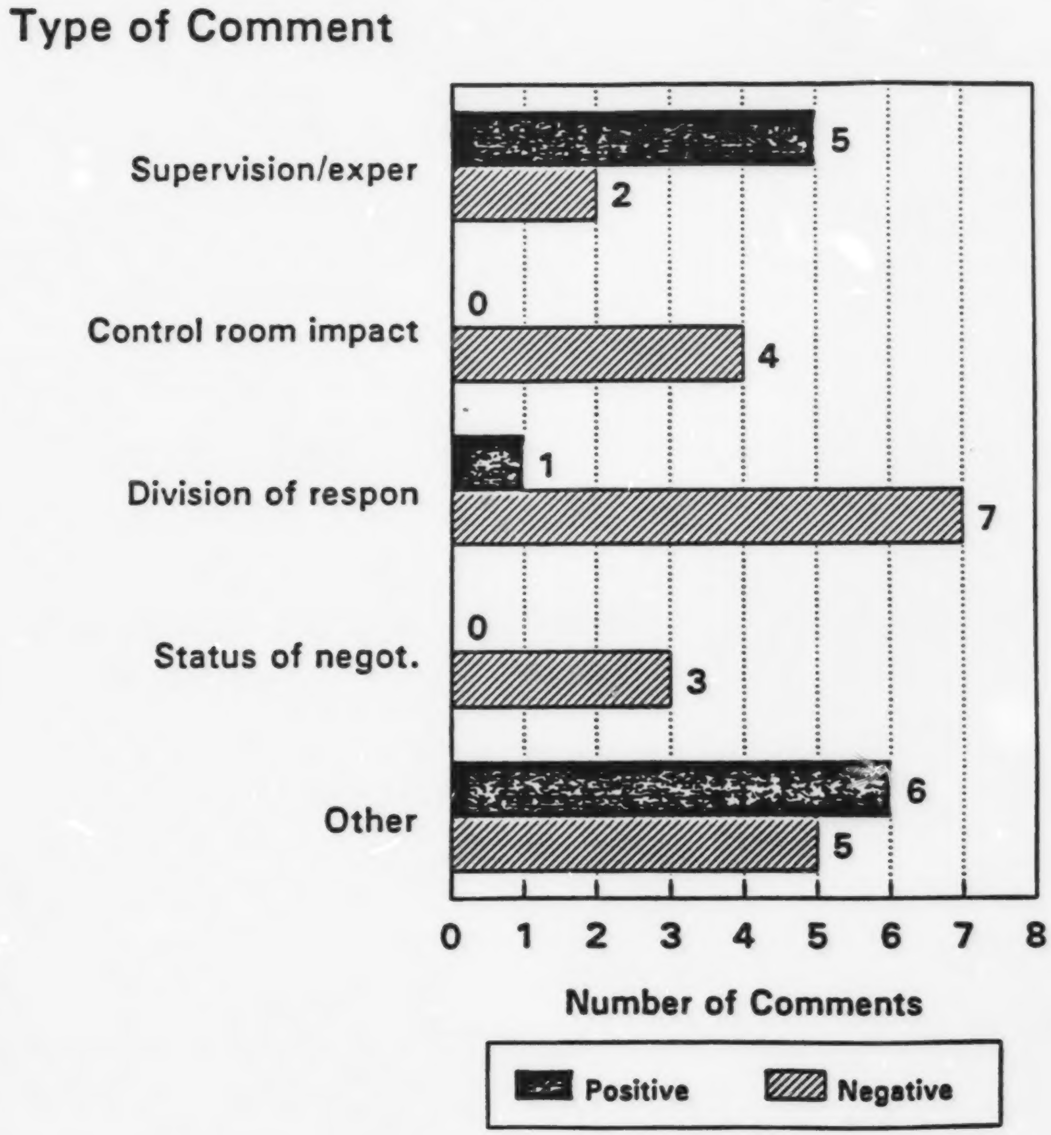
Comments About Management and Others



(a) Comments about the New Operating Structure: There were a total of 33 comments about the New Operating Structure, 12 positive and 21 negative. (Six respondents made positive comments, 13 made negative comments.) Two-thirds of these were classified into four categories -- supervision/experience in the field, impact on control room, division of responsibility and status of negotiations. The remainder were of a general or miscellaneous nature (eg. "works ok", "plan is fine", etc.). The four categories are described below in terms of examples given by respondents. Positive comments were made about the extra supervision provided (five) and the division of responsibility it provides (one). Negative comments were also made about the lack of supervisory training for the new SNOs (two). Other negative comments pinpointed impacts on the control room (four), a division of responsibility which was unclear (seven), and dissatisfaction with the status of the negotiations on the new structure (three).

Four of the six positive comments classified above were made by managers (SOS and SMS). No positive comments were made by Authorized or Unauthorized First Operators. Conversely, none of the negative comments were made by managers, whereas nine of the 16 were made by First Operators. See Figure 4.

Figure 4
Comments on New Operating Structure



4.2 Requirement 2 -- Carrying Out the Work Effectively

An effective communication system relies on the design of procedures and instrument so that the appropriate work is carried out. The procedures and instruments assist in carrying out the tasks of producing electrical energy. If a system is technically effective, its procedures and instruments should be able to be used to assist operators in carrying out their work effectively. We do not directly measure the effectiveness of the procedures and instruments, but we did ask operators to comment on the procedures and control room instrumentation which individuals felt were helpful in making decisions. These results are summarized in Figures 5 and 6.

4.2.1 Positive Comments about Procedures

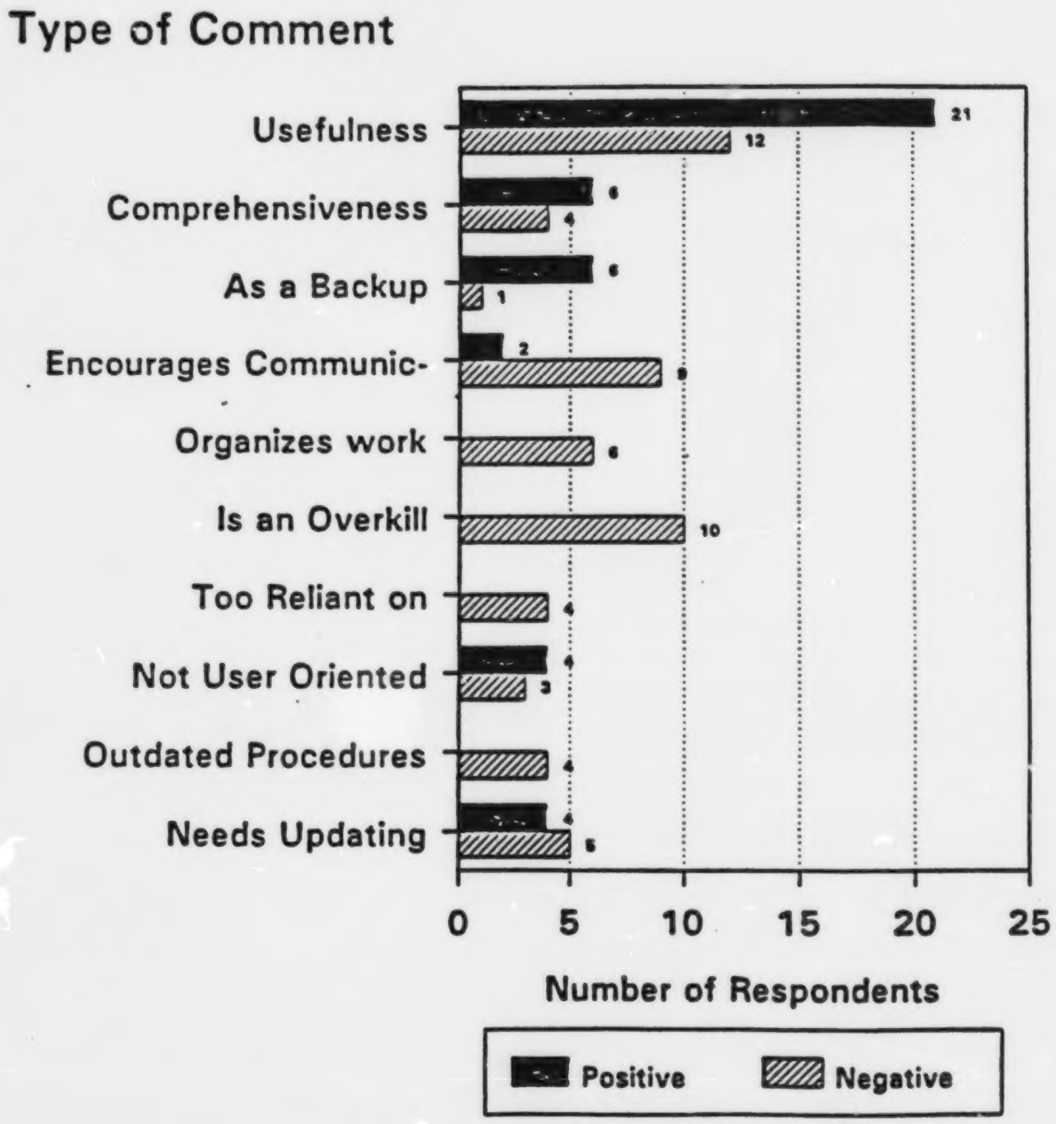
Figure 5 illustrates a large number of positive comments which individuals offered about the procedures they used in making decisions. Twenty-one (21) individuals provided examples and cases to illustrate how they relied on procedures and how they felt that they were an accurate and useful way to guide the organization's operations. The procedures were viewed as a good way to train individuals. There were positive comments on the way the operating manuals are being improved as a result of the recent revisions which are viewed as more accurate and "down-to-earth."

Individuals also offered positive comments on the comprehensiveness of procedures and their appropriateness as a source of back-up. To some people (six), the procedures provided a logical and detailed flow of critical steps and a description of maintenance requirements. They were also viewed as a useful backup and enhancement to communication, "something to fall back on when things go wrong, and as a good reference check for infrequent events."

Other positive comments on procedures were made about the documentation group's work of making the procedures more "user friendly." There were also positive comments about the updates themselves and the process of revising and updating.

Figure 5

Control Room Procedures



4.2.2 Not-so-positive Comments about Procedures

Most of the less positive comments about procedures questioned their
(i) usefulness/ reliability,
(ii) ability to encourage communication, and
(iii) conciseness and organization.

Some individuals (12) indicated that several procedures were not useful because they did not work, or were written for "worst case" scenarios. This is reflected in one comment "Certain procedures do not work and we cannot trust them."

Nine individuals suggested that the procedures do not encourage good communication. That is the procedures do not involve some key people, are very complicated, and encourage a procedural mentality.

Other individuals (10) indicated that there were too many procedures, and "they were a bit of an overkill." They felt that they were faced with too much information, some of which was not needed but given to them because everyone got it. Some procedures are "too specific, offer too much detail, and seem to be required for even the simplest tasks."

Several other not-so-positive comments were offered about procedures. There were comments which indicated that the procedures could be better organized and improved by: indexing, consistency, conciseness, a point (bullet) rather than paragraph style, and so forth. Other people indicated that the procedures are outdated (five) and need updating (four). There were also comments that we may be too reliant on procedures.

4.2.3 Suggestions for Improving Procedures

Individuals offered a range of comments for making the procedures more useful. They suggested that it was very rare for people to face a situation which did not have some general procedure or manufacturer's manuals and worker experience. However, nine people suggested that there were many situations where procedures did not exist -- in situations of shutting down a unit, running a safety check, running a stand-up generator, trouble shooting situations, and a wide range of situations which are in a "grey area." Many of these situations require judgement.

While most people felt that it was not practical to try to develop procedures for every situation, a first priority might go to sorting out the existing procedures so that they were more useful and accessible. There were suggestions that we do not want to "proceduralize" ourselves to death and that it might be useful to develop ways to deviate or by-pass ineffective procedures. In addition, four people suggested that joint-problem-solving and consultation procedures might be appropriate.

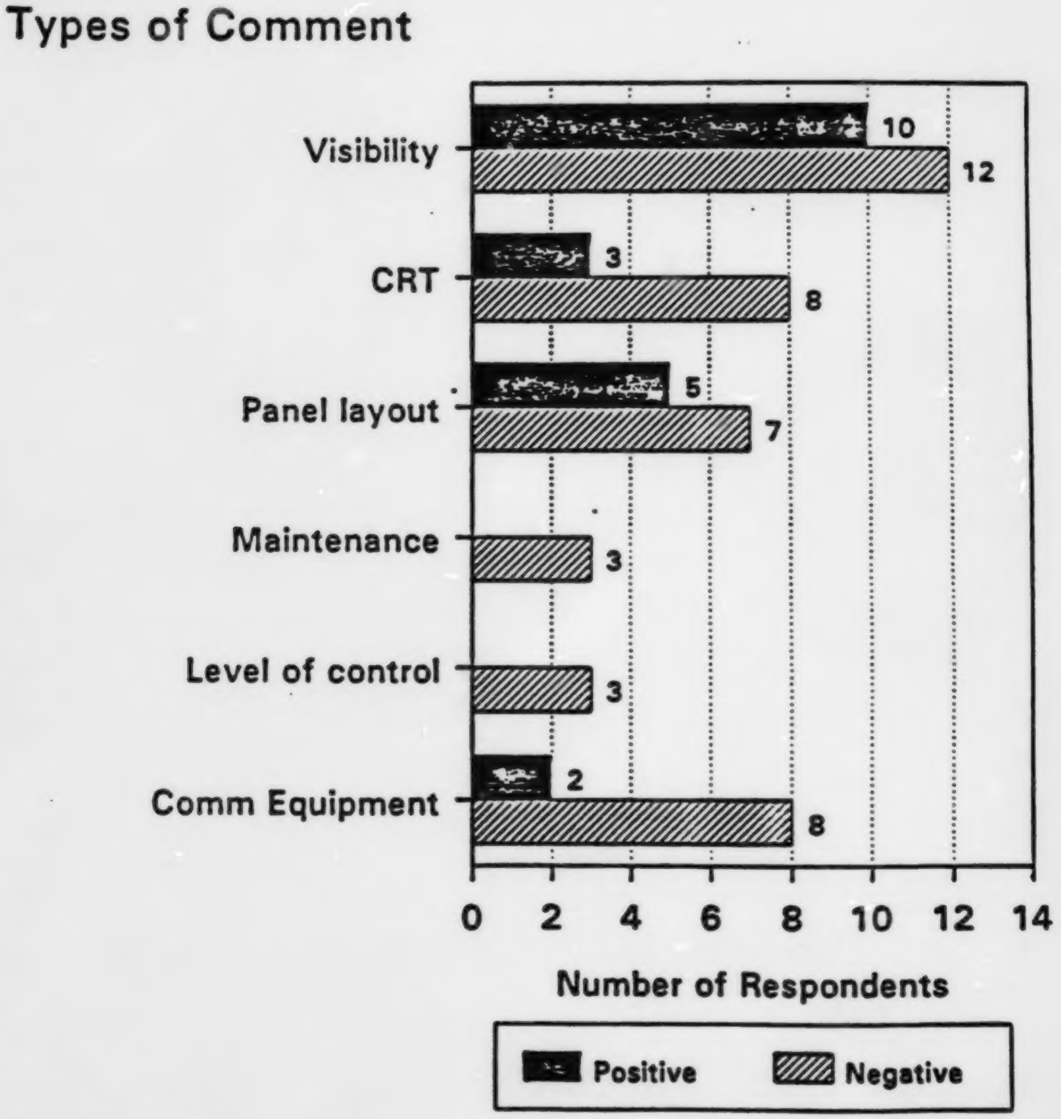
There were several comments (11) on what people should do when procedures are not working. Most of these comments relate to consulting others, but also rely on an overall process of: thinking, developing a flow sheet, devising our own procedures from our systems knowledge, having a written plan of attack, and consultation and approval from others.

4.2.4 Positive Comments about Instruments

Figure 6 illustrates the positive comments on instruments used in making decisions and diagnosing problems. They referred more generally to the control room instruments but field operators made comments about the instrumentation they used throughout the plant.

There were several positive comments on the instruments, most coming from people who were working in close proximity to the control room (15 of the 20 comments). Many of the positive comments (10 of 20) -- on encoder valve lights, alarm lights, the ease of reading flashing lights -- refer to the visibility of the instruments and their ease of reading.

Figure 6
Usefulness of Instruments



There were also positive comments on the instruments on the CRT (three), the panel layout (five), and the communications equipment. Individuals felt that the CRT had several useful displays such as the historical trends, critical safety parameters, and other computer information screens (these comments came from ANO, SOS, and SS). There were a variety of positive comments on the arrangement of the panel (from various people -- SS, fuel handlers, and ANO) which refer to the panel layout, the row of flashing lights, and trend lines. There were also positive comments about the communications equipment -- the phones, radios, headsets (these comments came from F-H and NO).

4.2.5 Not-so-positive Comments about Instruments

A range of people in the control room had a number of less positive things to say about the instruments. Most of the not-so-positive comments came from people associated with the control room (26/40).

The largest number of negative comments (12) referred to the visibility of the instruments (most of these comments came from people in the control room). Two people indicated that the control panel was cluttered and wide, but most of the comments criticised the types of instruments and dials. Operators suggested that "some dials were too small, different dials do similar things, and operators cannot read them without physically walking over to them (especially the LED display). Some operator suggested that the displays at Darlington and Bruce "B" were superior to the ones in Bruce "A."

There were criticisms that the CRT (six of eight from control room people) was hard to read because of the green colour, size of trend lines, clarity of the subject matter being displayed, and the scale of the charts and graphs. Many of these people suggested that the coloured trend lines at Bruce "B" would be easier to read than the green screens. The colours would allow operators to differentiate different trends.

Some operators criticized the panel arrangement (five of eight from control room people) for various reasons. For example, operators have to physically get up and go over and read certain dials and have to leave the control room because some controls are in the back room. In addition, some people suggested that the control room was becoming too cluttered, and that the desk arrangement might be improved by taking into account what has been done elsewhere, recognizing the information needs of the operators.

There were several negative comments on some of the communication equipment (eg., telephones, radios) and the difficulties with maintenance. Most of these comments came from people working in the field. Field people indicated that the radios sometimes do not work because of blind spots. "It was hard to get deficient radios fixed or find ones which worked well." There were also negative comments about the P.A. system (it was difficult to hear it), and suggestions that head phones might be more appropriate for some communications. Some instruments were difficult to maintain because their parts were located in hard to reach places or were inaccessible.

There was one final set of comments which described the degree of control that operators have. That is, some operators were appreciative of the fact that their dials and instruments allow them to directly control the operations rather than being controlled by the computer.

4.2.6 Summary: The Usefulness of Procedures and Instruments

The procedures and instruments provide one view of a communications system and its appropriateness for assisting operators with their requirements. Generally, operators rely on procedures and they are viewed as extremely useful and comprehensive. However, there are concerns of reliability and about an over-reliance on procedures. Operators also made several positive comments about the visibility of instruments and their layout, although they offered a number of criticisms which might improve visibility and the type of instruments and dials which might be used.

Overall, the results point out the need to design procedures and instruments which are technically efficient as well as humanly efficient. Procedures can be designed to be scientifically useful, but they also have to respond to individual needs such as user friendliness, a perception of reliability and face validity, and must not overload the user. These comments also recognize the need to construct a process where procedures are designed so that operators feel they are useful and user friendly.

4.3 Requirement 3 -- Diagnosing Routine and Unusual Events

In most formal organizations, there is the need for communication structures which are specifically concerned with sensing relevant changes affecting the future operations. Such structures may devote their entire energies to the anticipation of changes and the resolution of problems. Ideally, these tasks prevent more major problems from occurring.

In some ways, the job of certain operators might be compared to that of a medical doctor, in that both need to diagnose problems based on some external symptoms. For example, a medical doctor may take a patient's temperature and blood pressure, and may ask a few questions about how the patient has been feeling lately, and then make a diagnosis of the patient's condition. In a similar way, operators have to draw conclusions about what is going on within the system, based on the control panel indicators, and what they know about what else is going on (ie., maintenance activities, etc.,) that might affect the system.

The events which people found easiest to diagnose were those which were visible and where there was a direct cause and effect linkage between the problem and its potential solution. These events were not systemic or complex. Rather, they were mechanistic and simple, such as water leakage from a valve, a seal ring which was sticking, a loss of air pressure, and so forth.

The events which seemed most difficult to diagnose were more systemic and complex, as the effects were not directly linked to one part or machine. The most difficult problems seemed to emerge from systems such as electrical systems where there are several sources of supply, computer systems where it is not possible to diagnose whether the computer hardware or software is causing the problem, or other systems which require the integrated functioning of a number of parts, machines, or other systems.

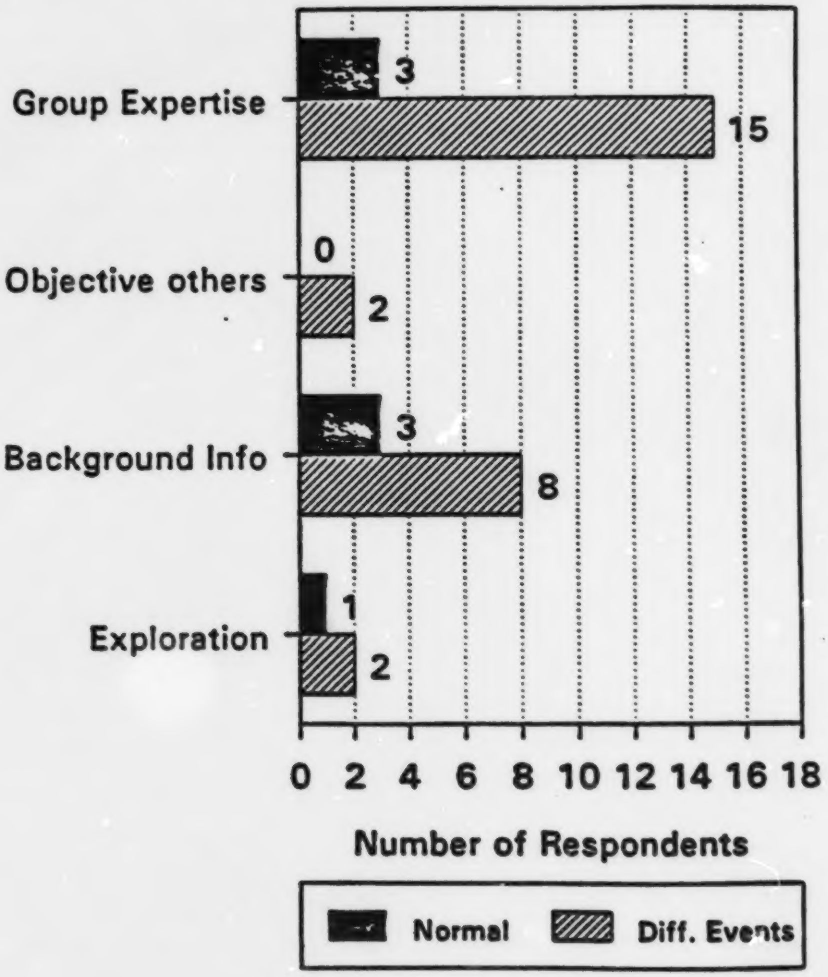
Figure 7 illustrates the non-standard ways operators used to diagnose such complex problems. Most of the individuals (15) who were asked this question, relied on consultation and input from other people. Seven individuals said that they relied on group consultation while another eight indicated that they depended on the advice of individuals such as peers, supervisors, people in the field, or individuals from the technical unit.

4.3.1 Summary: Diagnosing Difficult Problems

These results do not suggest that individuals and groups are the only mechanisms for diagnosing difficult events, but it may be the most practised. Systems problem-solving might recognize all these methods as stages in making a decisions. In stage I, operators gather information in an informal manner from peers and co-workers or by simple observation. Where there is no immediate solution, historical information, statistical trends, and experience is sought and a subjective solution is drawn in stage II. Group brainstorming and generation of alternatives are utilized in stage III. Stage IV of such a problem-solving process embodies the use of information which combines the use of creative alternatives (stage III) with trends and statistics (stage II).

Figure 7
Diagnosing Problems

Methods of Diagnosis



4.4 Miscommunications and Reactions to Information Overload

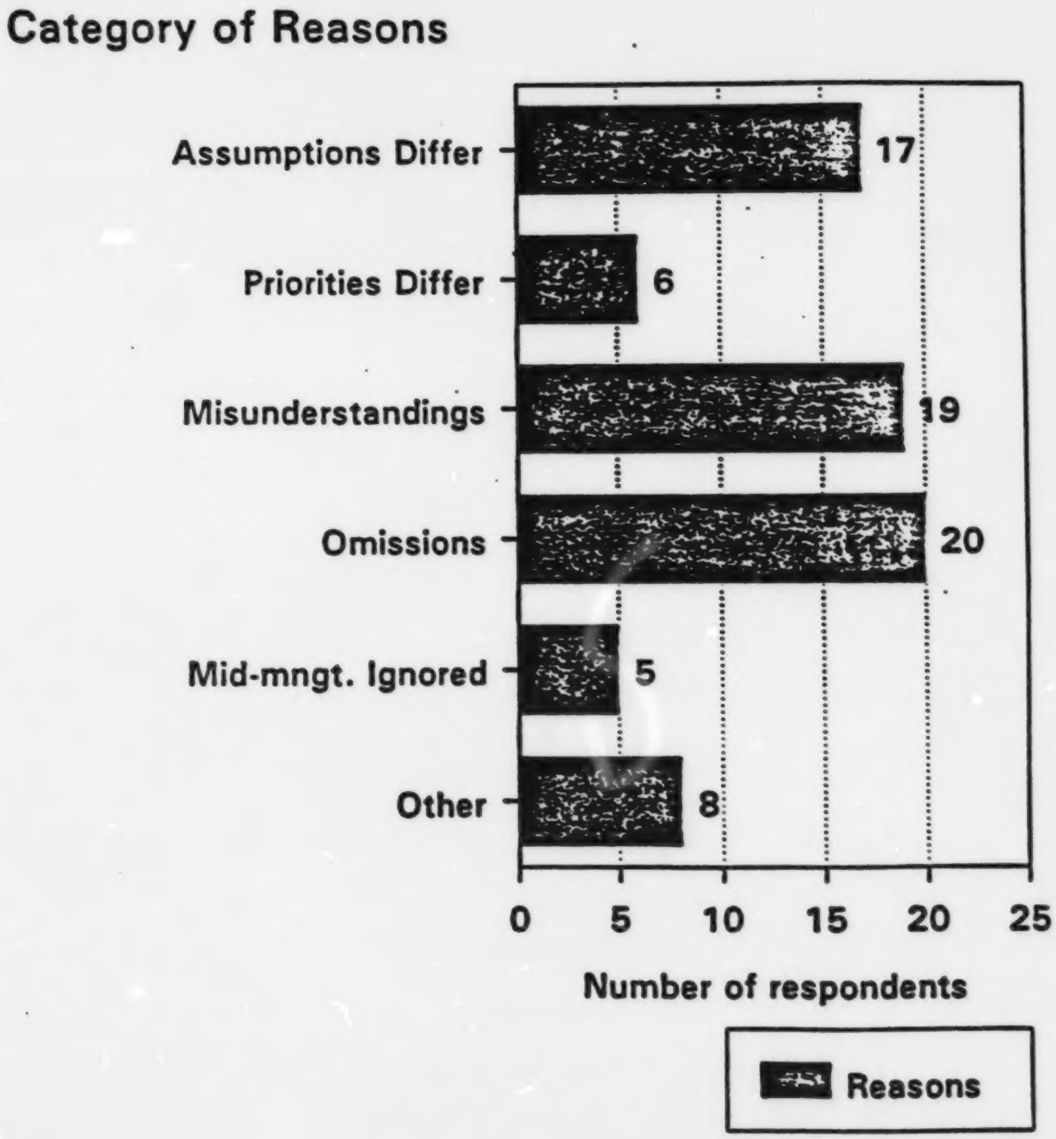
As people in nuclear power plants seek to carry out their tasks and coordinate their work, there are times when miscommunications occur which may lead to problems.

4.4.1 Reasons for Miscommunications

Figure 8 is a summary of the types of miscommunications which people identified in our interviews. Five general types of incidents were identified: assumptions differing, priorities differing, misunderstandings, omissions, and being ignored.

> (a) Assumptions Differing: In a large number of incidents, miscommunications occurred because there appeared to be differences in the "assumptions" or framework of the communicators. Differences in assumptions occur when people are speaking the same language but are not communicating because the words mean different things due to the particular knowledge, experience, or viewpoint of the other. There are some well known incidents of this: for example, when a pilot incorrectly assumed that the navigator's readings identified the correct airport before descending, or of maintenance workers providing fuel for an airplane assuming that the digital reading was a measure of gallons rather than litres.
>
> Many of the differences in assumptions in the sample of people we interviewed were attributed to a wide variance in the turnover stories, some of which might relate to the varied levels of experience of some of the operators. In fact, inexperience was identified by seven of the 16 people who commented (in four of the seven cases, the inexperience of the SNO and NO was identified: in one case, the U-O-MPO was identified). It appears that a large number of these types of incidents occur at the beginning of the shift (eight of the differences in assumptions occurred at the beginning of the shift, and in five cases, the turnover report was identified as the cause).
>
> The interviewees also indicated that the way procedures are written can lead to differences in assumptions. Some operators suggested that the procedures were often written from two different frameworks, those of the technical people and those who are responsible for carrying out the job. There seemed to be a number of suggestions that recent attempts to involve operators in drafting procedures has been a useful mechanism for devising more realistic procedures.

Figure 8
Reasons for Miscommunications



In addition, there were illustrations of people in the field relying "too much on procedures and not using their common sense and experience". This concern is identified in the following statement:

> I see people doing only what is required on the OTO. They are not thinking of implications. They are robots.

(b) Priorities Differing: A number of people (six) suggested that differences in priorities was another cause of miscommunication. Different groups failed to recognize the priorities of others, and managers and supervisors did not provide information on priorities, overall plans, or general information about corporate objectives. The following comments illustrate this:

> SS has priorities but they are not the same for the SOS.

(c) Misunderstandings: People also said that many misunderstandings occurred in communicating. Misunderstandings emerged in several ways and were reported as often by people in the field as by control room people. Many of the comments referred to people who used different terminology. Misunderstandings emerged from differences in terminology between shifts, differences between "rookie" engineers and operators, and misunderstandings which arise during the turnover, and between the command centre and the field. There were also indications of mistakes about what units were being worked on, and which valves were isolated (on which unit). One field operator said that he gave information to the wrong ANO (eg., should have been given to Unit 2 rather than 3). In other cases, field operators on overtime and working on a different unit, reported that they sometimes (absent-mindedly) went to the wrong unit. There were also indications of classic misunderstandings:

> We were transferring heavy water to a tanker. We overfilled it. He thought I knew exactly how much the tanker would hold. I thought he was watching it being filled and was going to tell me to stop. It overfilled.

There is a standard set of terms and codes that people expect to hear from NO's and SNO's. Often, new NO's and SNO's use non-standard codes. There is a lack of common terminology with some people.

(d) Omissions: A large number of omissions seem to occur in transferring information. In most cases, these omissions did not seem to occur at any set time during the shift. As many occurred at the beginning as the end of the shift.

Some omissions seemed to evolve from the seemingly impossible task of transferring 12 hours of information during a 15 minute turnover (six of the 20 people referred to the turnover report). A typical comment seemed to be "There is so much information that you have to keep track of; it is easy to lose sight of little things." There were several stories of failures of the turnover person to describe deviations from procedures and particular valves which were open. There were also comments that the turnover report was inadequate or incomplete, that the previous person had omitted certain details, and that it was not possible to tell what was done.

Other examples of omissions included "people not telling others what they were doing." These were cases where some "field operators did routine work and did not inform others" and "outside work groups not informing others of the status of work that they did."

(e) Being ignored: Communications between SOS and the two maintenance groups can be confusing due to the different priorities each group has. One supervisor's comment illustrates some views that middle management is ignored. Five individuals had similar statements.

> My level is not receiving communication from managers as to the direction of the organization. Middle management is not part of the solution. We have a lack of understanding and input into the direction of the organization. Most of the dialogue is between top management and the union.

4.4.2 Suggestions Offered for Reducing Miscommunications

There were a range of suggestions for reducing miscommunications, and most of them related to training. Twelve of the 17 comments on miscommunication referred to some form of training in improving communications by:

(i) group training,
(ii) verbal communications,
(iii) written communications, and
(iv) general suggestions.

Comments on group training (two) referred to assisting group members in their communications as a team. Seven individuals felt that there was a need for interpersonal training which related to providing a clear, precise, and exact message, perhaps based on standard codes and terminology. "Training in other areas is very adequate, but little time and attention is directed to how to provide feedback and deliver written communication." Six individuals mentioned the need for training which emphasized written communication for developing consistent reporting practices.

> There are procedures which say that we must keep a log and various reports, but the procedures do not specify how to do this. So, different people have different ideas as to what should go into logs and different ways of stating a message.

Other general comments on training indicated the need for learning how to prioritize, for improving safety, dealing with "red phone" procedures, and for assuring a safe turnover of work assignments. The remaining five of the 17 suggestions for reducing miscommunications covered a range of suggestions to improve record keeping. Suggestions included installing a large white board to clearly show the status of a shut down unit, making procedures more user friendly (rather than technical), and assuring that information is recorded and passed on from management.

4.4.3 Summary: Communication and Overload

Miscommunications may be reactions which evolve from systems rather than procedural problems. That is, misunderstandings, omissions, and so forth may be a result of an overload of information and from the "assumed solution" that more information is better than little information. A systems perspective would suggest that we recognize that the solutions to these problems may evolve from understanding why overload occurs.

5. DISCUSSION

The following section is organized in two parts. The first part addresses the specific tasks set out in the contract. The second provides a discussion of information beyond those tasks but relevant in a general way to issues of communication within the nuclear power plant.

5.1 Specific Tasks

Of the six tasks specified in the contract, the four relating to patterns of interaction and communication were addressed in the previous sections. The remaining tasks, of defining the command structure of the operations component and proposing methods for measuring the degree of intelligibility and understanding, are addressed below.

5.1.1 Command Structure

Every one of the 30 interviewees reported that they were organized under the New Operating Structure. One of the major innovations of the new structure has been to eliminate the position of Second Operator and create the position of field SNO, whose major duty is to provide supervision in the field. It is our understanding that this change has been associated with changes in authority and communication structures. The ANO is responsible for setting Unit priorities and communicating the priorities of the management team. His task is essentially that of work direction, and this is associated with a linkage between the SOS and the ANO, and between the ANO and the SNO. The SNO is responsible for field supervision, and this is associated with a personnel supervision linkage between the SOS and the SNO and between the SNO and the NO. These linkages represent what we understand to be the intended organization of the operations component under the New Operating Structure.

The information we obtained about communication and dependency linkages, together with information about the nature and purpose of communications, can be combined to identify what is the effective organization of the operations component.

As a starting point, the main linkages that exist can be examined in terms of communications and task dependencies. Diagram 4 below shows the three main links for the positions of SOS, ANO, SNO and NO (the distances between nodes are arbitrary). The main links were, in decreasing order: for the SOS, with the ANO, SS (not shown) and SNO; for the ANO, with the SNO, SOS and NO; for the SNO, with the ANO, NO and SOS; for the NO, with the SNO, ANO and SCPO (not shown). The same picture results if links are determined from dependencies rather than communications and, with one exception, the linkages are identical to the intended organization. The exception is the direct and relatively strong linkage between the ANO and NO, which was not, so far as we are aware, explicit in the New Operating Structure.

We can get more detailed information about the nature of this structure by examining the kinds of activities associated with the different linkages.

For the SOS-ANO link, the associated activities most frequently mentioned by the SOSs included: planning, checking on job status/priorities, problem solving, authorization. ANOs mentioned the same activities. This linkage appears therefore to be used for its intended function of work direction and authorization.

For the SOS-SNO link the associated activities mentioned by SOSs included: manpower issues, approval of jobs, signing work reports. SNOs mentioned communicating about SOS's jobs, providing information about job status. The sample we had here is small (two SOSs and two SNOs), but from the information available the link appears to be used for providing information from the field about jobs as well as about personnel supervision issues.

For the ANO-SNO link, ANOs mentioned: planning, relaying work to be done, checking on job status, problem solving, receiving reports. SNOs mentioned receiving information about jobs to be done, providing information on job status, providing reports. These activities are consistent with the intended function of this linkage.

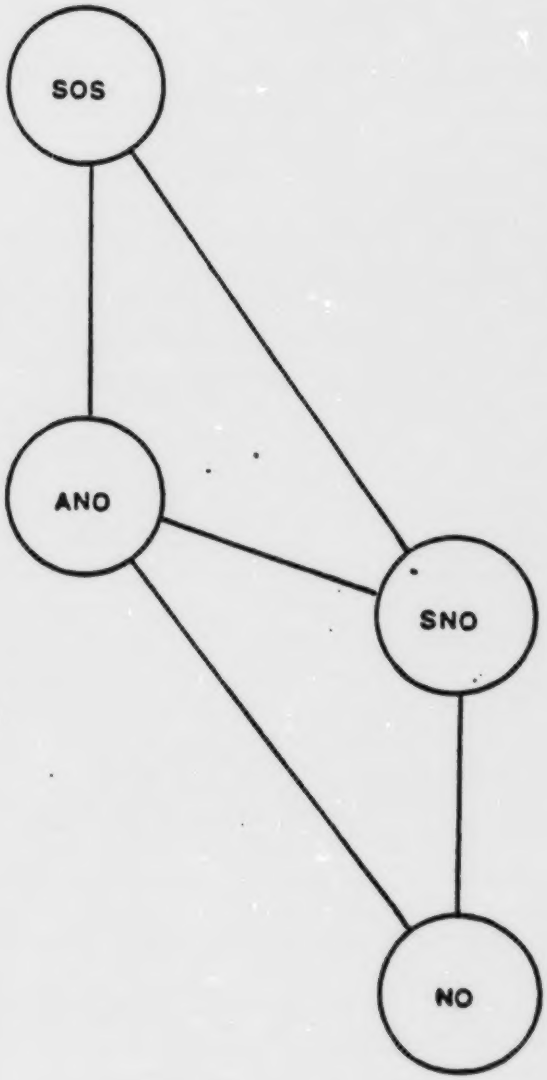
For the SNO-NO linkage, SNOs mentioned: explaining jobs, giving OTOs (Orders to Operate), providing information/help, checking and verifying jobs. NOs mentioned: receiving work plans/job schedules, receiving information/help, providing information/reports on job status. These activities are consistent with the linkage's intended function of field supervision.

For the ANO-NO link, ANOs mentioned: assigning jobs, providing specific task details, communicating about problems and current status of jobs. NOs mentioned: receiving job assignments, communicating about current status/problems, providing feedback on jobs. So far as we know this linkage was not explicit in the New Operating Structure.

The linkages apparent in Diagram 4 indicate two instances where the organizational principle of unity of command has been violated, creating a potential for division of authority, confusion in reporting relationships and diffusion of responsibility. First, the link from SOS to SNO bypasses the ANO, the SNO's direct supervisor on work direction issues. This may be justified on the grounds that the direct SOS-SNO link is for personnel supervision issues only. This, however, raises questions of whether issues of work direction versus personnel supervision are always clearly distinct. Second, the ANO-NO link bypasses the SNO, the NO's direct supervisor. Given the need for the ANO to co-ordinate field operations on SSTs and to be in continuous receipt of field information, a linkage of this kind seems to be essential. On the other hand, it appears to be used for job assignment, and as such could result in the NO receiving conflicting commands from two superiors, or the SNO being unable to properly supervise NOs because they have been assigned tasks without his knowledge.

While some of the negative comments made by respondents about the New Operating Structure are consistent with the above observations there were also positive comments, mainly about improved supervision, increased expertise in the field and a reduction in the indirect supervisory burden on ANOs. In this respect, the new structure may be having its intended effect. What may be important is to ensure that it does not also produce unintended consequences of a less positive nature.

Diagram 4
Reporting Relationships Based on Communication Linkages


SOS
ANO
SNO
NO

5.1.2 Methods for Measuring Intelligibility and Understanding in Control Room Communications

This question raises many interesting issues that might in themselves require a whole report to explore thoroughly. What we have tried to do here is to sketch some possible avenues of investigation, but in enough detail that they could be implemented by research professionals.

One area where intelligibility seems to be an issue is that of paging. A considerable amount of control room/field communications are initiated over the public address system, where a field operator is paged by name. We frequently heard of failures of this system, attributed to the fact that people were not able to hear or distinguish their own name when paged, and one of us observed such a failure when, arriving early for an interview in the field, the scheduled interviewee was paged three or four times without responding. For a visitor to the plant this seems quite understandable, since there are many areas where the background noise level makes paged messages difficult or impossible to decipher. Nevertheless, it is to be expected that field operators would learn to interpret paged messages more effectively than the casual visitor, and the degree of unintelligibility to experienced personnel becomes an empirical question that could be approached in a number of direct ways.

An initial way to approach this issue would be a simple observational study, where a random sample of paged messages would be selected and the outcomes recorded. A more interesting approach would be to carry out some "action research", with the potential not only for measurement but for change. For example, in terms of information theory, "noise" increases the uncertainty within a communication system. If noise cannot be reduced, then the alternative is to reduce uncertainty by increasing the redundancy in the message. This is why the standard procedure in military operations is to repeat critical commands over field telephones ("Do NOT, repeat do NOT, attack"). If we accept for the time being that noise is a problem with the paging system then it would be possible to conduct experiments on the effects of increasing redundancy. One approach might be to reduce uncertainty about who is being paged by a stage-wise reduction in the array of possibilities. For example, a code could be used for different levels of operator (different codes for SNO, NO etc.), or for different units. The codes might be communicated by clearly distinguishable and audible tones or chords, for example, in much the same way that different colours are presently used to visually distinguish different units. Each page message would then be preceded by the group code, followed by the individual name. The code would alert members of the specified group that a message for one of them was coming (one level of uncertainty reduction) which should then increase the likelihood that the subsequent individual name would be correctly identified. It might be possible, given the shift structure of the plant, to test this kind of approach in some shifts and retain the present approach in others. This would provide observational measures of the present system as well as an experimental test of an alternative.

Another approach follows from the recognition that a situation like this may encourage varying degrees of intentional lack of response to paging. Field people are working in a busy, noisy, and sometimes stressful environment. There is a paging system that is widely understood to be uncertain. Under these conditions it would take a saint not to be tempted to ignore the occasional call. This is a situation that readily lends itself to analysis within a signal detection paradigm. In this approach, outcomes are typically classified in a four-fold table, with two ways of being right and two ways of being wrong. In the present instance, an outcome is correct when an operator responds when paged, and doesn't respond when not paged. Similarly, an outcome is wrong when an operator doesn't respond when paged (a "miss"), or responds when not paged (a "false alarm"). In an unbiased situation, where errors occur only because of "noise" and with no intentional lapses, we would expect to observe errors of both types. That is, operators should respond to pages they didn't have as well not responding to pages they did have. As it happened, we heard comments only about "misses", errors of non-response. There were no comments about people phoning in when they had not been called.

The likelihood of each of the two types of error in the unbiased situation depends on the subjective probability of a page occurring. However, given the frequent use of the public address system, the expectation of a paged message should be high enough that errors of both types would occur. One way to investigate this would be a straightforward observational study, where responses to a random sample of paged messages would be classified in terms of the four-fold table of outcomes. If no, or few, "false alarms" occurred then the results would suggest an intentional ignoring of messages, for which there might be a number of possible remedies.

Another commonly-voiced concern was the unintelligibility of reports, often attributed to BIMS. There is a feeling that when operators with poor keyboard skills have to enter work reports on BIMS they do not give enough information to clearly specify what they have done. If true, this is a potentially serious problem. There are two questions here. Are reports insufficiently specified? If so, is this due to the requirement to type them? The first question could be approached by selecting a sample of reports and giving them to an appropriate panel for interpretation. Members of the panel might independently write their interpretation of each report, and then compare the different interpretations for consistency. Or a scoring form for reports might be designed, based on how well it specifies things like which component was worked on, where was it located, what was done to it, etc.? Panel members could then score reports. Whichever method is used could be used also to investigate the effects of BIMS on intelligibility, by comparing BIMS and non-BIMS generated reports (random or matched samples). The non-BIMS reports would first be transcribed to BIMS and printed, so that the comparison would test content only and not differences due to format or appearance.

5.2 A Socio-Technical View of Organizational Design

We have already described our results and have tried to emphasize how they help us understand specific systemic issues within a nuclear power plant. In the following section, we offer a discussion of some the more important results by drawing on a socio-technical framework.

A systems approach suggests than an organization has to respond to certain technical requirements such as management/coordination, production, and adaptation. A socio-technical system builds on the systems approach and recognizes that an organization's technical design requires an effective social or human system. The following discussion illustrates certain principles which might be recognized in the design of a social system which is compatible with its technical system.[7] Each principle is first presented and then described using the data from our study.

5.2.1 Compatibility -- Usefulness of Procedures and Instruments

If the objective of design is to create a system which is capable of self-modification, then the process of designing procedures and instruments must rely on input and involvement of the operators. This principle suggests that an organization design which relies on team responsibility and worker initiative cannot be created by fiat. The process of design must be compatible with its objectives.

In our study, many of the operators offered comments on the design of procedures and instruments. The majority of positive and negative comments were concerned with usefulness and visibility. Other related comments described how operators used the procedures and instruments -- their comprehensiveness, their use as a backup, and their ability to encourage communication and organize work. There were also comments on the CRT and the panel layout.

In improving the procedures and instruments, there were a number of comments and suggestions which pointed to the need to sort out and improve the procedures which were now available, rather than developing new procedures. A number of comments pointed toward the need to develop procedures for consultation and problem-solving. Such ideas rely on developing ways of thinking, using experience, using group knowledge, and so forth in improving ways to resolve situations which could not be handled by existing procedures.

If the objective of the procedures and instruments is to be useful and reliable to the operator, then operator involvement and insight might be important in their development. A necessary condition for involvement requires that people are given the opportunity to participate in the design of those procedures and instruments they will have to use. An example of this kind of participation is the work of the documentation group to update procedures. Other mechanisms for increasing involvement might include worker suggestions, task forces on safety and quality service groups.

5.2.2 Minimal Critical Specification of Procedures

In designing procedures, it may be necessary to be precise about what has to be done, but it is rarely necessary to be precise about how it should be done. This implies the minimal critical specification of tasks, the minimal critical allocation of tasks to jobs, and the specification of objectives, standards, or outputs.

In our study, a large number of people indicated that procedures were a bit of an overkill, that people may become too reliant on them, that they were not user oriented, and that they were outdated and needed updating. These comments typify an organization where procedures are highly specialized and where almost all issues and problems are referred to some "uniform system" of rules and procedures.

Organizations which are highly proceduralized have often been criticized as "organizations of robots or unthinking people," "organizations which are overloaded with information for all purposes," or as "organizations which would never work if everyone did what they were told and worked to rule." These criticisms illustrate the dilemma of trying to describe everything with procedures and rules. Even if procedures could be defined for every circumstance, they would be potentially unreliable if they were not updated regularly. Operators would have to be well trained for the new procedures and constantly reminded and controlled to make sure that procedures are not broken or forgotten, misapplied, and so forth.

This principle suggests that procedures might be more effectively designed by focusing on "outputs, objectives, or what has to be done," rather than "inputs and descriptions of rules of how they should be done." That is, procedures should specify what decisions should be made, what checks and ideas should be considered, and the standards that should be maintained. They might not be as specific on how the operator should carry out each individual task. In an oil spill crisis, for example, the goal would not be to make sure than operators followed every procedure, because such situations require novel decision-making. Rather, the goal would be to encourage operators to focus on outputs such as cleaning up the oil spill as quickly as possible by recognizing procedural checks, standards, and so forth.

Procedures which specify more than is needed can result in an overload of procedures because there is no priority given to the importance of standards or philosophy. In addition, highly specified procedures sometimes miss important and efficient ways of resolving problems. The advantage of focusing on outputs or standards is that it suggests a priority and a philosophy. People learn to work within a priority.

5.2.3 The Socio-Technical Criterion in Dealing with Problems

This principle states that variances or problems, if they cannot be eliminated, should be controlled as near to their point of origin as possible. The fewer the variances which are dealt with by other levels in the organization, the fewer the levels of supervision that are required and the more complete the jobs are for the job holder.

Several people provided ideas on how people handled problems or dealt with difficult and unprogrammed events such as the breakdown of specific parts, a machine failure, the failure to take action at a critical time, and so on. Many of these procedures and management structures are designed to assist in making decisions when these events happen. In some circumstances, information was transferred to top management for decision-making, to the Technical Unit, or to other functions or roles. This results in delays and little learning for operational people to take on responsibility for problem-solving. In other cases, "memos" and other formal means were used to assure accuracy, with little reliance on methods which encourage people to internalize the new information or procedures.

When we asked these operators about the most effective way of dealing with difficult events, they did not point to the need to rely on top management. Rather, the network diagrams illustrate that managers and other supervisors are not always the key decision-makers. The ANO is the centre of most of the communications and decisions. When key events and problems occur, there is a need to rely on group expertise and the judgements of others. This suggests that much of the interaction occurs around the ANO role working in consultation with other roles.

The key variances or difficulties we identified referred to situations which were systemic and complex, such as computer systems, electrical systems, plumbing systems, machine systems and other systems which require the integrated functioning of parts, machines, and other systems. These events seem to require input and ideas from other specialized groups. Rather than having people work together because of their functional responsibility as a manager, these decisions require the expertise of operators.

In the future, it might be appropriate to formalize such linkages where people in different units are working together. Thus, formal linkages might be identified where the Technical Unit is more involved with operational problem-solving or having operational people work with the Technical Unit for assigned periods of time.

5.2.4 The Multifunctional Principle -- Organism vs. Mechanism

A traditional form of organization requires people to perform highly specialized and fractionated tasks where assignments, roles, and procedures are specifically designated for certain individuals. An organic form of organization suggests that the same functions and requirements can be performed by a variety of people, roles, procedures, and so forth.

There were several comments about turnovers which indicated the highly specialized nature of the organization's design. Individuals often suggested that several miscommunications occurred during turnover because assumptions differed or because of omissions. During turnover, there seemed to be the impossible task of transferring information gathered during 12 hours of work and having to pass this on during a 5-15 minute interchange. This difficulty is compounded as workers feel anxious about "getting off after working 12 hours," and incoming workers whose "minds are often in other places when coming to work." In short, it may not naturally be a receptive climate for communication to occur.

Another characteristic of turnover is that it gives an appearance of a parallel communication channel but in reality there may be strong elements of serial communication. At least one respondent stated that if he is given wrong turnover information then he can check with the SOS or SNO, that in effect there are many back-up systems in place. However, turnover information is also passed on in a hierarchical manner. The NOs provide information to the SNO, who passes on information to the ANO, who transmits it to the SOS. An omission or error at any stage is not necessarily going to be corrected at the next. In other words, there may be less redundancy in the communication system than is implied by the "parallel process" of person-to-person turnover.

Parallel communication channels require the opportunity to provide for correction. If the communication channels are too specialized and the roles do not interact, then, there is less possibility for self-correction. Thus, team meetings may provide more potential for self-correction than communication conducted along strict hierarchical lines. Organization with parallel communication channels is more dynamic because it offers a range of responses and checks, and is especially useful if the environment is offering a range of responses which are changing.

5.2.5 Boundaries -- Grouping Principles

Organization boundaries are usually drawn so as to group people and activities on the basis of one or more of three criteria: technology, territory, time. In many organizations, the technologies of different groups or units are key in determining how groups are organized. Grouping by technology is typically seen in the telephone industry where the telephone switchboard is located in one area and other machines in another. Grouping by territory can be seen when machines are put in a common area because of spatial contiguity, or because they are more easily answerable to one supervisor. Grouping by time might correspond to shift schedules (separation of shift workers from day workers).

This grouping principle suggests that the more the control of activities within a department become the responsibility of the members, the more the role of planner/supervisor/foreman/manager is concentrated in boundary activities. In such a grouping, operators have greater input into plans and can carry out roles of ensuring that the team has adequate resources. They can play a major role in coordinating activities with those of other departments, and foreseeing changes that are likely to impinge upon them.

In the nuclear power industry, we see examples of operators working in a common area because of the common technologies which they operate; the ANO and people in the control room are working with similar technologies. In the same way, NOs and trades people are organized in certain areas of the plant close to the technologies they operate. Several other examples are present:

(i) separation of maintenance and operational personnel because of location of technology and spatial proximity,

(ii) separation of shift workers from day workers (from Friday at 4:00 p.m., to Monday at 9:00 a.m., there is a 65 hour period (five shifts) before a shift worker contacts a day worker),

(iii) shift crews often take over from different people than they relieve, limiting the potential for mutual exchange or reciprocity concerning how the Unit is turned-over.

This method of organization is convenient and defensible, but possesses certain disadvantages, in that it may erect barriers to the exchange of knowledge and experience. An example is the separation that exists between the operations component and the Planning Unit. The Planning Unit passes out a weekly plan of activities which appears frequently to create feelings of resentment among operational personnel. Comments were made to the effect that "The plan has got nothing to do with what I have to do in my job. It tells me what I have done. The projected dates on the future are meaningless. The tasks are just wish-lists." There may be some pardonable exaggeration in this interviewee's comments; the point is that ANOs and field people feel they have a great deal of knowledge of priorities and resources, and the capability to carry out the work. Being organized into separate departments, planning shares little knowledge with the operators, who have direct knowledge of the capabilities of accomplishing a job within certain times.

Under some circumstances, working groups can acquire and handle a greater degree of autonomy and learn to manage their own planning and managerial activities. This creates a possibility to set their own goals and outputs and set up their own standards for controlling and motivating others. The role of planners/ supervisors/ managers become one of assisting and facilitating rather than directing and controlling.

5.2.6 Information Flow

This principle states that information systems should be designed to provide information in the first place to the point where action on the basis of it is needed. In some organizations, information is passed through managers, technical departments, and supervisors before it is passed on to those people who need to use it to make decisions.

In the nuclear power plant we studied, there may be several examples of information being gathered in a way that was more useful to central purposes than to those who were working with it. For example, the BIMS system seems to be a useful tool for coordinating managerial action, planning, and displaying information about the operations. However, workers found it cumbersome, time consuming, and unreliable. In another example, operational personnel sometimes complained about confusing terminology, and suggested that the terminology is more useful for engineering and technical purposes than it is for operators.

Properly directed, information systems can supply a work team with exactly the right type and amount of information to enable them to learn to control and manage the problems within their responsibilities. If an information system is designed to respond to managerial or technical needs first, it may have much more information than necessary.

5.2.7 Support Congruence

This principle states that a system of social support should be designed to reinforce the behaviours which the organization structure is designed to elicit. If, for example, an organization is designed to encourage operator and team responsibility for safe and efficient operations, then personnel systems should be congruent with these objectives.

In the nuclear power industry, there seems to be a general philosophy that safety and efficiency are the highest priorities. However, a number of comments were made which seemed to question the congruence between current support systems and these priorities. There were questions about selection, training, promotion, and procedures which might at times be incongruent with safety or efficiency. Operators made comments which indicated that others were not properly trained and selected for specific types of jobs. In addition, there were several comments on the need for training and procedures which promoted group problem-solving and consultation, since operators were often presented with situations which demanded group work and responsibility.

5.2.8 Design and Human Values

This principle suggests that the objective of a design should be to provide a high quality of work, by recognizing the efficiency needs of a technical system and individuals' needs for growth, development, learning, and involvement. It might be argued that not all people are interested in their growth and development and would sooner "treat their job as a job and not a career". In the same sense, some organizational designs may not assist people who wish to learn and develop their career. The objective is to treat the human design as being as important as the technical design.

In the Bruce "A" plant there might be several questions about the way that some jobs are designed. For example, the SCPO job seems to have very little responsibility and content that would provide a person with much opportunity for learning and growth. Unless an ANO takes an interest in mentoring and coaching a SCPO, the person in this job may become frustrated. In addition, the SCPO job is split between two panels, which might cause some confusion of information on the panels, and also a lack of a sense of involvement or of task completion.

With further study, it might be possible to pinpoint other job design weaknesses. For example, the ANO position seems to be one which has a great deal of learning and stimulation, and might even be too varied and stimulating. Another example is the SNO position in Unit 0 and Fuel Handling, where individuals seem to rotate between SNO and NO positions, so that a person who is the "boss" at one time is the subordinate at another.

A definition of the elements of human and social design might be quite subjective, and depend on individual needs, career objectives, and cultural background. However, most socio-technical advocates would suggest that there are certain social and psychological elements which are as important as the technical design. They might include:

(i) the need for the content of the job to be reasonably demanding and to provide some variety,

(ii) the need to be able to learn on the job and to go on learning,

(iii) the need for some minimal area of decision-making that the individual can call his/her own,

(iv) the need for some minimal degree of social support and recognition in the workplace,

(v) the need for the individual to be able to relate what he/she does and what he/she produces to his/her social life, and

(vi) the need to feel that the job leads to some sort of desirable future (not necessarily promotion).[8]

5.2.9 Incompletion

If a systems framework is used in designing organizations, there is a need to recognize that design is a reiterative process. A nuclear power plant is such a system which is constantly undergoing changes in response to new technologies and new ideas from management. Design teams, composed of workers and managers, can provide a mechanism for involving others and for encouraging a reiterative process. As designs are completed, new members should be recruited and old ones rotated.

5.3 Summary

The preceding paragraphs offer a discussion of how some of our findings might be interpreted using a socio-technical systems framework. The interest and logic underlying such a discussion should not provoke a series of recommendations which indicate how managers might implement this approach. The socio-technical approach relies on an implementation process where members of the organization are involved in the process of the design they will operate. In doing this, the design is tailored to the needs of the organization, rather than to some design group.

6. RECOMMENDATIONS

In keeping with the exploratory nature of the project, the recommendations offered here are about areas for further information collection and research.

6.1 Linkages with Other Units

The information provided to us indicated that linkages between the operations component and other organizational components are weak, and that other components are perceived to be remote, inaccessible and unresponsive (see Section 4.1.3). If this view is accurate, then these relationships should be further examined. In particular, the relationship between the operations component and the Technical and Planning Units might be looked at more closely. However, it has to be borne in mind that this is the view from inside the operations component. There may be a natural tendency for a sense of elitism to develop in the production unit of any organization (since it produces the fundamental outputs) that might readily give rise to perceptions that it "carries" the organization without receiving the full appreciation and support it deserves from other components. It would therefore be desirable to round out the present view with information collected in other components about their communications and relations with the operations component.

6.2 The New Operating Structure

The effectiveness of the New Operating Structure is something that should probably be monitored from time to time. The potential advantages of the new structure include: increased supervision in the field; increased expertise in the field; decreased indirect supervisory load on ANOs. Potential disadvantages include: ambiguity of reporting relationships (in both the SOS-ANO-SNO relationship and the ANO-SNO-NO relationship); reduced expertise in the control room. (See Section 4.1.3, Subsection (a), and Section 5.1.1.) The related issue of the SCPO position is something that should also be looked at. From a communications and information processing perspective there appear to be potential problems. From the information provided by other positions, linkages with the SCPO position appear to be very weak (see Section 3.1.2). In addition, working on two units reportedly causes information to get confused. If confusion is indeed a problem, there may be ways to introduce or amplify physical or temporal cues to differentiate units.

6.3 Procedures for Reporting

Although procedures exist for a large number of activities, some respondents mentioned the lack of procedures governing communication and reports. One context in which this could be further examined is that of measuring the intelligibility of reports, discussed in the previous chapter. If it were true that reports have become less intelligible because they have to be entered on BIMS then it might be necessary to develop procedures (and aids) covering BIMS reporting.

6.4 Unit Rotation/Dedication

According to ANOs each nuclear unit has its own operating characteristics, and perhaps its own "feel". The units also have different performance records, as can be seen from the production charts displayed in the plant. As presently organized, control room and field operators on the nuclear units rotate through the units. An alternative form of organization would be to dedicate operators to particular units. Both forms of organization have potential advantages and disadvantages. Rotation may be fairer in some senses -- no one is stuck with a unit that has a record of problems. Rotation may also provide a wider range of experiences than dedication to a single unit. On the other hand, dedication would provide a continuity of experience that might lead to a deeper knowledge of a particular unit. It might also improve communication and information processing. Miscommunications due to confusing information about units (or confusing the physical units themselves) would presumably be reduced. Unit "teams" might develop a body of unit-specific terminology that was more precise and more consistent than present terminology. Being responsible for a single unit could lead to a sense of ownership that might be more motivating and rewarding than the present organization of work.

Obviously this is a large issue. It could be investigated theoretically, by identifying and analyzing the various implications of different work designs, and empirically, by directly comparing two or more plants organized on different principles.

6.5 Training

Operators already go through a rigorous set of training procedures to enhance their skills and understanding of nuclear power plants. Much of this training increases the operator's familiarity with new procedures, equipments, and ways of working. There are also valuable training simulations.

We heard several requests for a different type of training, one which puts more emphasis on skills like working together, team decision-making, and so forth. This type of training emphasizes "extra-rational" skills for making difficult decisions when normal procedures are not working. Such skills require creativity, lateral thinking, group-problem-solving skills, and so forth. Further research would be necessary to define the skills which would be useful.

7. REFERENCES

1. Moray, N.P. & Huey, B.M., 1988. Human factors research and nuclear safety. Washington, D.C.: National Academy Press, 3-4.

2. Flanagan, John C., 1949. Critical requirements: A new approach to employee evaluation. Personnel Psychology, 2, 419-425. Janz, T., Hellervik, L. & Gilmore, D.C., 1986. Behavior Description Interviewing. Newton, Mass.: Allyn and Bacon, Inc.

3. Bavelas, Janet B., Bavelas, Alex, & Schaefer, Brian A., 1978. A method for constructing student-generated faculty-evaluation questionnaires. Victoria, University of Victoria. Bavelas, Alex, 1942. "A method for investigating individual and group ideology." Sociometry, 5, 371-377. Barthol, R.P. and Bridge, R.G., 1968. "The echo multi-response method for surveying value and influence in groups." Psychological Reports, 22, 1345-1354.

4. Weiner, N. 1954. The human use of human beings. Doubleday & Company, Inc.,

5. Bavelas, A., MacGregor, J., and Safayeni, F., 1983. A conceptual model of the office. Journal of Information Science, 5, 169-172.

6. Safayeni, F., MacGregor, J., Lee, E., & Bavelas, A., 1987. Social and task related impacts of office automation: An exploratory field test of a model of the office. Human Systems Management, 7, 103-144.

7. The principles are taken from: Cherns, Albert, 1976. "The principles of socio-technical design." Human Relations, 29, 783-792.

8. Thorsrud, E. 1972. Policy as a learning process. In A.B. Cherns, R.. Sinclair, & W.I Jenkins, (Eds.) Social science and government: Policies and problems. London: Tavistock. See also: Cunningham, J.B. and White, T. 1984.
Quality of Working Life: Contemporary Cases. Ottawa: DSS

APPENDIX I

Nuclear Plant Control Room Communications Questionnaire

Introduction

We are researchers from the Centre for Organizational Research and Effectiveness (CORE). We have been contracted by the AECB to study and document the kinds of communications which occur in and out of and within the control room of a nuclear power plant. We have had several preliminary discussions with members of management, the union, and the AECB group at this plant, as well as an extensive discussion with one First Operator. These discussions have helped us gain a general understanding of the nature of the activities performed within the control room and the relationship between the control room and other groups within the plant.

We can assure you of the complete confidentiality of your comments. When we report on this study, under no conditions will we specifically refer to you individually. Therefore we encourage you to be as open and frank as possible in your responses to the questions.

The study will focus on various aspects of your job situation, with particular emphasis on the communications and decision making aspects of your work. Since you work different shifts (ie, days, nights, weekends, etc.), we would like you to consider the questions in terms of the day shift operations at the plant. Also, in your answers you can assume that the plant is operating in a "normal" state.

Communications and Work Activity Questions

In the first set of questions, we would like to find out about your communications with others, both inside and outside of the control room. We understand that the types of activities you are involved with in your job change somewhat throughout the shift, so we will begin by dividing the shift into three parts--the beginning of the shift (the first hour or so), the middle of the shift, and the end of the shift (the last hour or so). We will ask you similar kinds of questions about your communications during each of these parts of the shift.

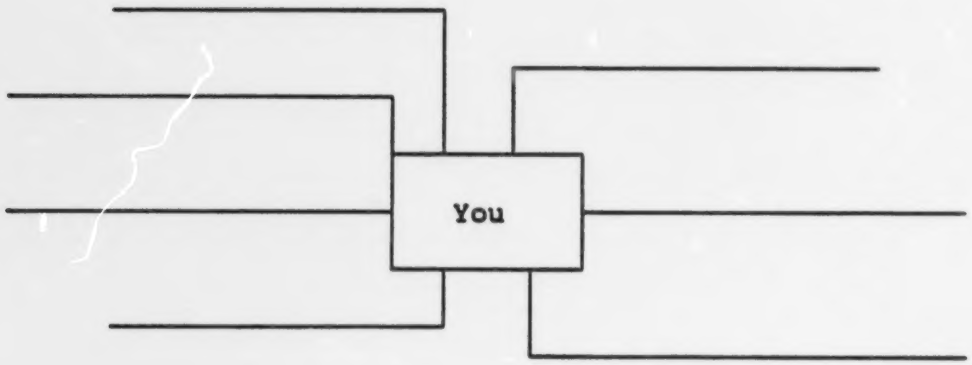
A. Beginning of the Shift

1) On the diagram below, please indicate all of the major communication linkages which you might have with others at the beginning of your shift (the first hour or so). [These linkages might be with individuals (eg. Shift Supervisor) or with groups (eg. Field Operators, Maintenance, etc.)]. For each of these linkages:

i) What would be the mode of communication usually used (ie, phone, radio, face to face, etc.)?

ii) Approximately how often does this type of communication happen (for example per shift)?

iii) Could you give some typical examples of reasons why you would communicate with this person (or group)?



2) In addition to these communications, could you give some examples of other activities which you typically perform at the beginning of your shift?

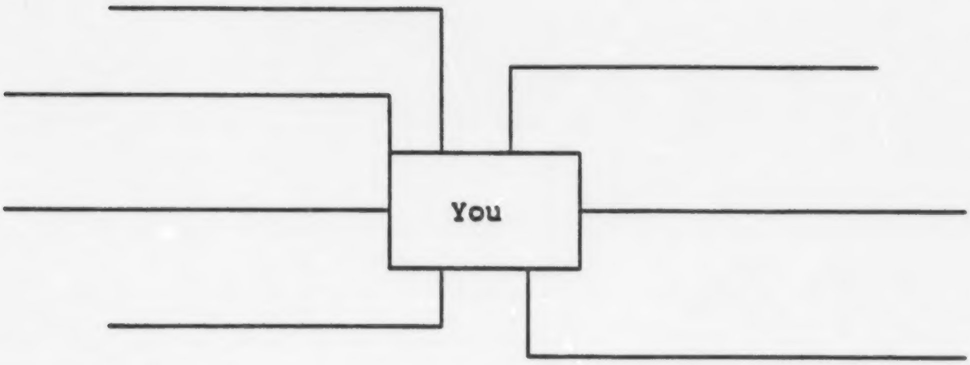
B. Middle of the Shift

3) On the diagram below, please indicate all of the major communication linkages you may have with others during the middle part of your shift. [These linkages might be with individuals (eg. Shift Supervisor) or with groups (eg. Field Operators, Maintenance, etc.)]. For each of these linkages:

i) What would be the mode of communication usually used (ie. phone, radio, face to face, etc.)?

ii) Approximately how often does this type of communication happen (for example per shift)?

iii) Could you give some typical examples of reasons why you would communicate with this person (or group)?



4) In addition to these communications, could you give some examples of other activities which you typically perform during the middle part of your shift?

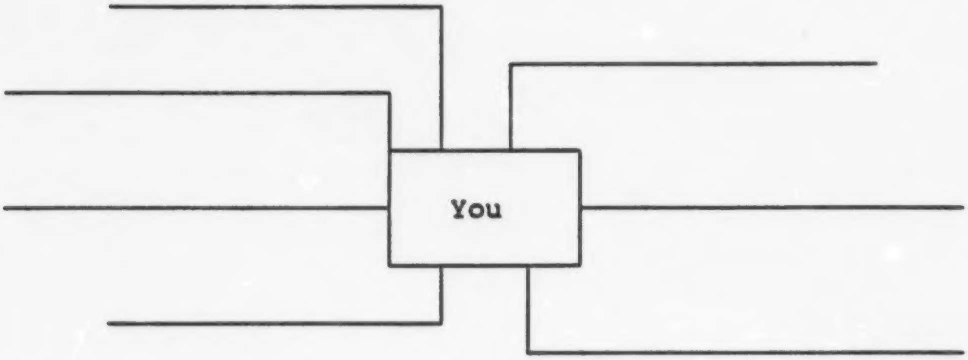
C. End of the Shift

5) On the diagram below, please indicate all of the major communication linkages you may have with others at the end of your shift (last hour or so). {These linkages might be with individuals (eg. Shift Supervisor) or with groups (eg. Field Operators, Maintenance, etc.)]. For each of these linkages:

   i) What would be the mode of communication usually used (ie. phone, radio, face to face, etc.)?

   ii) Approximately how often does this type of communication happen (for example per shift)?

   iii) Could you give some typical examples of reasons why you would communicate with this person (or group)?



4) In addition to these communications, could you give some examples of other activities which you typically perform during the middle part of your shift?

D. Work Relationships

Now considering the various communications linkages which you have just identified for the different parts of the shift, we would like to ask you some general questions about the nature of your working relationship with each of these individuals or groups. [Note: the following questions no longer need to be asked with respect to a particular time period in the shift.]

7) For each of these individuals or groups:

   i) Could you give some specific examples of things that this individual or group does that are helpful to you in your job?

   ii) Could you give some specific examples of things that this individual or group does that are not so helpful to you in your job?

E. Miscommunications

8) In all working relationships, there are times when miscommunications occur, which may or may not lead to problems. For each of the individuals or groups identified earlier:

   i) Could you give some examples of miscommunications that have occurred, in which, for instance, something you said was misinterpreted by the other person, or you misinterpreted something they said?

   ii) Is there a time in the shift when these types of miscommunication tend to occur most frequently...
      - Beginning of Shift?
      - Middle of Shift?
      - End of Shift?

F. Control Room Instrumentation

9) In addition to verbal communication, we realize that you rely extensively on signals provided by the instrumentation panel. Could you give us some examples of instrumentation (dials, computer screens, etc.) which you feel are very helpful to you in your job?

10) Could you give us some examples of instrumentation (dials, computer screens, etc.) which you feel are not so helpful to you in your job?

Decision Making Questions

G. Procedures

In the next set of questions, we are interested in gaining an understanding of how you go about the process of diagnosing unusual events and deciding on appropriate corrective actions. We are familiar with the problem solving strategy used at Ontario Hydro (ie. event oriented as opposed to symptom oriented).

11) We understand that there are a large number of procedures which have been prepared to help you make decisions in your job. Could you give us some examples of procedures which you consider to be very helpful to you in your job?

12) Could you give us some examples of procedures which are not so helpful to you in your job?

13) Do situations ever arise for which there are no established procedures to follow, and you must rely on your own judgement and experience in order to handle the situation? Could you give some examples?

    i) Do you feel it is necessary to develop procedures for these types of situations?

H. Event Diagnosis

(First Operators Only) In some ways, your job as first operator might be compared to that of a medical doctor, in that both you and the doctor need to be able to diagnose problems based on some external symptoms. For example, the medical doctor may take a patient's temperature and blood pressure, and may ask a few questions about how the patient has been feeling lately, and then make a diagnosis of the patient's condition, In a similar way, in your job you draw conclusions about what is going on with the system, based on control panel indicators, and what you know about what else is going on (ie. maintenance activities, etc.) that might affect the system,

In the medical situation, there may be cases in which the symptoms can be interpreted in a variety of ways. For example, a sore throat and cough could be symptoms of a common cold, or they could be only the outward indicators of a much more serious condition, such as throat cancer. The doctor arrives at the correct diagnosis by gaining additional information which tends to rule out incorrect diagnoses.

14) Could you describe a situation based on your experience of an upset condition in which the root cause was relatively easy to diagnose and correct? How did you arrive at the correct diagnosis? Who else was involved? [Analogous to a medical doctor correctly diagnosing a common cold].

15) Could you describe a situation based on your experience of an upset condition in which the root cause was more difficult to diagnose? How did you arrive at the correct diagnosis in this case? Who else was involved? [Analogous to a medical doctor correctly diagnosing throat cancer].

APPENDIX II

COMMUNICATIONS AND SYSTEMS PRINCIPLES: A SELECTIVE LITERATURE REVIEW

ABSTRACT

General systems theory offers one perspective for defining and understanding organizational communications. This paper presents a set of general systems principles and illustrates how they might be useful for improving organizational communications. It then offers a discussion of socio-technical principles which might be useful for designing jobs in a nuclear power plant.

1. INTRODUCTION

The last twenty years of management research and popular writings underscores the attention given to the subject of communication. Over the years, few other management topics have received so much interest and study. There exist a number of schools of thought which view the notion of communication from fundamentally different perspectives. These schools focus on a wide array of topics from clarity of message delivery, group dynamics, interpersonal relationship and organizational climate in communications. No single approach provides all the necessary tools for improving organizational communications. With such a variation of viewpoints, it is not surprising that a consensus has not been reached about the single best way to improve communication.

General systems theory is one metaphor or school describing how organizational activities can be explained. This report provides a way to view communication from a systems viewpoint. It first describes the basic elements of general systems theory and then highlights certain socio-technical principles. It then offers some suggestions for how these principles might be implemented in an organizational setting.

2 THE CENTRAL ROLE OF SYSTEMS THINKING IN ORGANIZATIONAL COMMUNICATIONS

2.1 General Systems Theory

General systems theory is based on an assumption that organizational events occur in much the same fashion as the interactions found in organism. Needs and problems develop in much the same way as they do in organisms, as the organization grows and maintains itself, seeks equilibrium in reaction to stresses and strains, and carries out the tasks which are most essential to its survival.

Growth and Preservation. Organizations and organisms both grow and preserve themselves and consume energy to do so. Animal and plant species grow by cellular division, which is maintained within the organism's constant internal environment. Energy can be stored in fats and oils for future needs. (e.g., for hibernation or seed germination). In a similar way, organizations grow by departmental division, which is maintained by individuals taking on specific roles and entering into ongoing relationships.

Organizational systems also seem to reveal tendencies to grow and maintain themselves. Growth is a dynamic process which suggests that subsystems will utilize their energies for growth and expansion activities. Katz and Kahn provide five reasons for explaining why growth activities override preservation in social organizations.[1] (1) The proficiency dynamic leads to an increase in organizational capabilities; (2) expansion is the simplest method of dealing with problems of internal strain; (3) expansion is also the most direct solution in coping with problems of a changing social environment; (4) bureaucratic role systems in their nature permit of ready elaboration; and (5) organizational ideology encourages growth aspirations. (Katz and Kahn, 1965:100)

Government funded bureaucracies, such as a hospitals, illustrate a dynamic of growth. Despite the best efforts of decision-makers to control it, departments seem to take on a life of their own. Budgets grow, departments multiply, and staff are added. The only effective check might be the election of a cost cutting, deficit reducing government. The repercussions might be severe -- layoffs, slashed budgets, and the elimination of entire departments. The quick condemnation of organizational decision-makers in failing to control growth overlooks the fact that it may be quite natural.

Equilibrium. As social systems strive for growth and preservation, they create stresses and strains, which disrupt the normal equilibrium. This principle suggests that any external or internal factor (stimulus) disrupting the system is countered by forces restoring it as closely as possible to its previous state. There is a tendency for systems to adjust, to seek balance in the light of change.

This equilibrium principle is best exemplified in observing the physiological functioning of the body, as adrenalin and white corpuscles are immediate responses to injury or illness. In organizations, there is a constant inertia or resistances to new changes which affect individual habits and group norms. This does not mean that organizational systems are never modified by change, but that they continually try to adjust to it.

In social systems, unlike biological systems, there is the suggestion that the organization will not simply restore itself to the prior equilibrium. The system reacts to changes by using resources for repair, maintenance, and growth.[2] A organization also reacts to inputs which are disruptive, such as economic depressions, etc.

System theory suggests that problems are a natural result of an organization adjusting to changes, as it seeks to repair itself or make adjustments and find a new equilibrium. That is, problems are not random occurrences.

Essential Tasks. All systems have to focus on a range of tasks--adaptive/regulative, coordinative, productive, and maintenance--in order to survive and grow. Tasks concerned with designing how the organization relates to its environment are called regulative functions. Coordinative functions are concerned with directing, coordinating, and assuring that inputs are utilized appropriately for producing outputs. The tasks concerned with the production of outputs might be called the production function; those tasks concerned with repairing and helping are labelled maintenance functions. Underlying these technical systems is the social system, which is made up of the values, beliefs, and interests of the participants. System problems result from certain parts of the system disrupting the equilibrium of other parts. Essentially, disruptions take the form of incompatibilities between the components of the larger system.

---

[1] Biological systems may not have the same inclination.

[2] The term "entropy" is used to describe an organizational system natural process of breakdown, which parallels the process of decay and death in organisms.

Systems problems may arise from incompatible subsystems. Each subsystem performs tasks so that it can grow and serve itself and the organization as a whole. The regulative/adaptive subsystem's tasks are to structure the organization so that it responds appropriately to the environment and, in doing so, attains credibility with the system's clientele. The tasks of the coordinative subsystem are to achieve administrative objectives through plans or budgets and provide logical support to other subsystems; the production subsystem is organized to achieve objectives concerned with the production of goods and services. The maintenance subsystem seeks to use its reserve of resources to maintain and repair any parts that wear out, and to provide staff services and support for the other subsystems.

Different and often conflicting needs and values are inherent in each of these subsystem's tasks. In a typical manufacturing organization, these differences manifest themselves in interdepartmental "warfare." Production fails to understand and appreciate the constant modification of products and plans of the adaptive research and development department. The management subsystem is commonly perceived as intrusive and top heavy. These differences are a reflection of the conflict inherent in the tasks acted out by the different subsystems.

The above principles describe the characteristics of a technical system. Every technical system is embedded in a social system and is influenced by its culture and values, by a set of generally acceptable practices, and by the roles the culture permits for its members. The tasks of the social system are generally concerned with the individual's growth and achievement within the norms defined by those involved, as well as the stimulation of these norms through new challenges and information; the task is oriented towards gaining commitment and morale.

The incompatibility between technical and social systems is one of the potentially most vivid systems interactions. The history of organization illustrates how "time and motion" study engineers sought to design the most efficient technical social system. These and other technical interventions have interfered with individuals who have needs for independence, variety, and control over their work.

2.2 Systems Communications

In a typical organization, communication occurs in a variety of oral, written, and nonverbal ways: daily meetings, sales forecasts, manuals and documents, letters, and telephone conversations. Even titles, signs, and office locations communicate messages.

People carry around ideas or pictures of how things ought to be.[3] They communicate distinct messages which are used to focus on a range of tasks -- for regulating, coordinating, maintaining, and innovating -- the organization's activities. Communications concerned with designing how the organization relates to its environment are called regulative functions. Production functions are concerned with directing, coordinating, and assuring that inputs are utilized appropriately for producing outputs. Communications concerned with the production of outputs are related to the production function; those communications concerned with repairing and helping are labelled maintenance functions. Underlying these technical communications, are a number of interactions related to the values, beliefs, and interests of the participants.

An organization, therefore, really has the need for four or five information systems which provide different types of information for different tasks.

1. Regulatory communications system deals with messages that relate to goal setting, task-defining, rule setting, and decision framing functions. These concern policy statements and directions, information for change, communications, idea-sharing, strategy development, and implementation.

2. The Coordinative information system maps the flow of messages relevant to the key tasks. These concern production, inventory, and invoice messages that employees need to complete their jobs.

3. The maintenance information system is that system which maps the messages pertaining to the maintenance and support of all places where decisions are made. These concern payroll, suggestions, grievances, training, performance, evaluation, and personnel message flow. It is concerned with organizational morale and social functions.

---

[3] Weiner, Norbert .us;The human use of human beings Garden City, N.Y.: Doubleday & Company, Inc. Anchor Books, 1954. See: Shannon, Claude E. and Weaver, Warren .us;The Mathematical Theory of Communication, The University of Illinois Press, Urbana Ill: 1964.

4. The production information allows information for making sure that the organization's outputs and services are accomplished.

5. Information for the social system allows for staff morale, teamwork, personal recognition, and awareness. Sometimes, this information is gossip-like and is much like the informal "grapevine."[4]

Several categorizations have been developed for describing the content of communication within organizations.[5] They classify information according to its functional use.[6]

According to some information theorists,[7] there is a need to change our conception of an organization and in its information needs. Instead of rationally gathering information for all purposes, it might be useful to think of an organization as having many of the same qualities as a biological system. The information system is not a highly organized system where everything follows prescribed laws. Rather, an organization's environment is constantly in the process of breakdown or disorganization, which parallels the process of decay and death in organisms. This degenerative process is called "entropy." With respect to the communication model, this means that there is a tendency for information to be lost, disorganized, and become less meaningful as it travels from the information source to the destination. The more complex or spread-out the process becomes, the greater the likelihood that this breakdown will occur. They also react to inputs which are disruptive, such as economic depressions, etc.

---

[4] Similar categories have been described by Rasberry, Robert W. and Lemoine, Laura Fletcher Effective Managerial Communication. Kent Publishing Company, Boston, Mass. 1986. pp. 84-86. See also Thayer, Lee 1967, "Communication and organization Theory," in Frank E.X. Dance (ed.) Human Communication Theory: Original Essays. New York, Holt, Rinehart and Winston, Inc., See also Thayer, Lee, 1961, Administrative Communication. Homewood, Ill: Richard D. Irwin., Inc.,

[5] See Berlo, D.K. 1960. The process of communication. New York: Holt, Rinehart and Winston. Greenbaum, H.H. 1974. "The audit of organizational communication." Academy of Management Journal. 17: 739-754; See Katz, D., and Kahn, R. 1966. The social psychology of organizations. New York: John Wiley & Sons. Redding, W.C. 1968. Communication with the organization: An interpretive reviews of theory and research. New York: Industrial Communication Council

[6] For example, Redding's three classifications were task, maintenance, and human; Berlo used categories called production, innovation, and maintenance: Greenbaum identified communication networks concern with regulation, maintenance, and information sharing.

[7] There are alternative information processing models. Rational models assume that people process all relevant information in order to maximize a relevant outcome. Limited Capacity models recognize human information processing limitations; the model recognizes the importance of cognitive heuristics and simplified information-processing demands. Experts are people with a large knowledge base in a particular context and are used to supplement simplified existing processing structures. Cybernetic information processing models are dynamic. Learning and the process of change may be altered by feedback. The information processing model outlined in this section is similar to a cybernetic model. It responds best within criteria of: (i) theoretical utility, (ii) descriptive accuracy, (iii) prescriptive value, and (iv) potential to suggest interventions consistent with typical information processing. See: Lord, Robert G. & Maher, Karen J. 1990. "Alternative information processing models and their implications for theory, research, and practice.

Two basic processes work to reduce entropy in the system. (i) feedback and (ii) redundancy. The inputs of a system consists of energy, as well as information, which furnishes signals to its functioning in relation to the environment. Feedback is the simplest type of information input found in all systems. The working parts of the social structure will feed back information about the effects of outputs on the operations and maintenance of the system. If there is no corrective device to deal with negative feedback, the system's internal structure will begin to break down.

Redundancy is a second basic process of reducing disorganization and decay. The more redundant a communication code, the less chance there is that entropy will impair information transfer. Open systems are based on a principle of equifinality, which suggests that different organizational policies and goals can be achieved with diverse inputs and varying environmental and internal activities. There are many ways to duplicate the same outputs because random events can come into play. The same procedures, processes, and inputs are not essential for many organizational processes.

The systems communications model may be quite appropriate for enhancing decision-making. The decision process is linked to the information process, and computers and information systems should be tailored to the way people think. [8] Structuring the information acquisition process to the way that decisions are made could result in more effective procedures for gathering good information. Decision-makers can search for both custom-made and already known alternatives. Information acquisition should vary over the stages of a decision varying from viewing to scanning, to understanding.

Academy of Management Review 15, 9-28.

[8] Keen, P.G.W., 1981. "Decision support systems: Translating analytic techniques into useful tools. Sloan Management Review, 21, 33-44.

Managers today are faced with the task of making decisions in increasingly complex and turbulent environments.[9] It is possible, in many decisions, to agree on the information which is required in making a decision. Even though there may be multiple indicators available, some indicators are more common than others, and people may feel that they may want to make a decision in a unique way. Many actions cannot be carried out by a single person and, in many cases, other people have to be convinced about the important of certain information.[10]

In this regard, information systems might be designed to respond to the true nature of managerial decision making. In stage I, managers gather information in an informal manner from peers and co-workers or by simple observation. When there is no immediate solution, historical information is sought and a subjective solution is drawn in stage II. Analytical methods involving statistics and modelling are utilized in stage III. Stage IV of the model embodies the use of information by the manager who combines the analytical techniques of stage III with subjective reasoning. The process is cyclical and more information is gained until a satisfactory decision is made. In more complex decision-making environments, a decision-maker may have to search beyond the local environment. The model is simply an attempt to observe behaviour and provide a suggestion for how people make decisions. Of course, all people may not make decisions in this way.

The systems communications model is exemplified in Mintzberg's four decision roles to capture different managerial decision-making activities (i) planning and voluntary change, (ii) decisions concerned with planning and voluntary change, (iii) decisions concerned with disturbances that come up suddenly and place pressures on the organization too great to ignore, and (iv) decisions involved with non-routine negotiations between organizations and individuals.[11] There is some indication that executives do act differently for different information requirements. For example, internal sources and verbal media were more preferred when the executives aimed at improving the organization, and they preferred to work closely with their upper level counterparts. On the other hand, when allocating resources, the executives again might prefer to use internal information, both verbal and written.[12] Various sources and media are more appropriate at different times of the decision-making process.

---

[9] Advanced technologies do not automatically increase the rationality of decision-making, especially in highly politicized or power-driven organizations. The internal politics of decision-making are often more important than the needs of the market-place, client, or demands of the external environment. See: Huber, George P., 1990. "A theory of the effects of advanced information technologies on organizational design, intelligence, and decision-making." Academy of Management Review, 15, 47-71. They also indicate that managers with proprietary inclinations were eventually converted or purged.

In organizations where power plays a key role, technical and financial information is often very valuable as a device in aiding the "persuasion" process. See: Shukla, R.K., 1982. "Influence of power bases in organizational decision-making: A contingency model." Decision Sciences, 13, 450-470. From the former hierarchy of position power, there is developing a hierarchy where people in responsible positions can make decisions. Power and resources now flows to centres of competence instead of to the traditional power centres.

[10] Heimer, Carol A. 1985. Allocating information costs in a negotiated information order: Inter-organizational constraints on decision making in Norwegian oil insurance. Administrative Science Quarterly, 30, 395-417.

The decision-maker attributes are important in the selection of information. That is, certain decision makers will demand certain types of very different information in decision-making.[13] This work has been extended to offer suggestions that information systems should be tailored to how one thinks.[14]

Systems Problem-solving vs. Traditional Problem-solving

Some problems are more systemic in that they are interrelated to other problems and to other aspects of the organization. It might involve making strategic decisions from a limited set of information, and communicating information in a reliable and valid way. Or, a manager may be faced with the task of communicating to people in the organization so that the information provided in critical, useful, and not overloading. In other words, systemic problems are related to and arise out of the complexity of the situation and require a communications approach which is systemic in nature, not mechanistic. A manager can communicate in different way -- resolving it, solving it, and dissolving it.[15]

---

[11] Mintzberg, H., 1973. The nature of managerial work. New York: Harper and Row.

[12] Jones, J.W. & McLeod, R., Jr. 1986. The structure of executive information systems: An exploratory analysis. Decision Sciences. 17, 200-249.

[13] See for example: Henderson, J.C., & Nutt, P.C. 1980., The influence of decision style on decision making behaviour. Management Science. 26, 372)386; Mason, R.O., & Mitroff, I.I. 1973. A program for research on management information systems. Management Science. 19; McKenney, J.L. & Keen, P.G.W. 1974, How managers' minds work. Harvard Business Review. 57, 115-126.

[14] These ideas can also be seen as extensions of some old ideas which advocated that information systems must support the decision process. See: March, J.G., & Simon, H. Organizations. New York: Wiley, 1958.

Systems communications seeks to "dissolve" while mechanistic communications tends to "solve" a problem. The "dissolution" of a systems problem is an adjustment between (1) the various subsystem's requirements, and (ii) each subsystem's technical requirements and those in the social underlying social system. This is in sharp contrast to the resolution and solution orientation of mechanistic communications which are appropriate for non-systemic types of organizational problems. Mechanistic problems can be easily and appropriately resolved or solved, while systemic problems seem to require dissolution approaches.

There are also a number of secondary differences between systems and mechanistic communications procedures. Table I provides a summary of these differences.

Mechanistic communications seeks to preserve and maintain the system as it grows and expands. The goal is to resolve or solve problems and to create solutions to stresses and strains which occur. It is concerned with maintaining the status quo, by "fixing" something which is "broken down."

As a nuclear power plant motor breaks down, the goal is to repair the broken part and get the nuclear plant running again. Such communications seeks to provide "repairs and replacements to broken parts," and is not concerned with trying to change the situation which caused the breakdowns.

The goal of systems communications is to search for causes to resolve the problem and prevent future problems. It seeks to assure that an organization's subsystems are performing their critical requirements and are working effectively. The problem-solver seeks to understand each subsystem's unique requirements and those forces affecting its performance. He/she would not try to solve problems associated with a nuclear power plant's failure, but would tackle problems affecting the relationship to other departments. For example, general systems communications would tackle a problem such as the repeated breakdown of communications within a nuclear power plant fleet. The goal would be to "dissolve" the problem through changing and adapting the circumstances surrounding it. Perhaps, there is an incongruence between the operator's ways of making a decision and the technical requirements of the plans and procedures. The plant might require extensive procedures which are not useful to effective decision-making.

---

[15] Russell Ackoff (1981). "The Art and Science of Mess Management." .us;Interfaces. 11, 1, 20-26. Problem resolution is an attempt to select a course of action that yields an outcome that "satisfices," or suffices or satisfies the circumstances. It may not be the "best" or "scientifically-right" solution, but is a "good enough" solution. Solving a problem is to come up with the best solution or answer, usually with scientific methods, techniques, and tools. It is a concern for the "right" solution, which "optimizes." Resolutions and solutions generally reflect the outcome of mechanistic communications approaches.

Dissolving a problem is an attempt to change the nature of the environment and circumstances affecting it. Systems communications is aimed at responding to problems by dealing with the environmental issues and events causing them. It is an attempt to deal with the systemic causes of a problem rather than the more obvious symptoms.

The methods of the two approaches differ considerably. Systems communications includes a process where the system is defined and then proceeds to try to understand the unique perspectives and relationships of the major subsystems. Mechanistic communications starts by isolating the broken components, then treats each broken part independently in order to repair and replace them.

Systems communications procedures seek to understand relationships and to provide a general picture of the situation. Mechanistic communications activities focus on finding the causes of the specific events, and is concerned with establishing scientific laws which are irrefutable.

In mechanistic communications, the problem-solver controls the research in fulfilling his/her need to know through experimentation and defining general solutions to problems. Systems communications is aimed at discovery or invention, in providing new approaches or ideas. There is interest in understanding the problem in a unique setting and to unveil how it is related to other events and activities. Understanding the systems forces underlying a problem gives rise to discoveries of how to respond.

The focus of mechanistic communications is on the development of scientific laws or procedures. With systems communications, researchers focus on essential properties of the system, on their relationships.

In mechanistic communications, the definition of the problem is controlled by the problem-solver. Considerable effort on the part of mechanistic problem-solvers goes into the correct definition of the problem. In systems communications, the problem is not directly defined. Specific details for a specific situation emerge naturally through an examination of systems forces, dynamics, and critical environments.

All problems can be analyzed, with varying degrees of success, using traditional mechanistic methods of communications. This is especially true in those cases where the problem is definable and distinguishable from other subsystems or systems.

Socio-technical Theory Socio-technical thinking (STS) has been part of our intellectual repertoire for over four decades. Beginning with the classic work of Trist and his colleagues in the British Coal mining industry, researchers from the Tavistock have assisted in developing applications throughout the world in a wide range of industries.[16]

In our view, the concepts outlining socio-technical theory are best defined in the principles outlined by Albert Cherns in 1971. A socio-technical system builds on the systems approach and recognizes that an organization's technical design requires a effective social or human system.[17]

> I - Compatibility -- Usefulness of Procedures and Instruments. If the objective of design is to create a system which is capable of self-modification, then the process of designing procedures and instruments must rely on input and involvement of the operators.
>
> II - Minimal Critical Specification of Procedures. In designing procedures, it may be necessary to be precise about what has to be done, but it is rarely necessary to be precise about how it should be done.
>
> III - The Socio-technical Criterion in Dealing with Problems. This principle states that variances or problems, if they cannot be eliminated, should be controlled as near to their point of origin as possible.
>
> IV - The Multifunctional Principle -- Organism vs. Mechanism. An organic form of organization suggests that the same functions and requirements can be performed by a variety of people, roles, procedures, and so forth.
>
> V - Boundaries -- Grouping principles. This grouping principle suggests that the more the control of activities within a department become the responsibility of the members, the more the role of

---

[16] One of the best historical accounts of socio-technical theory is contained in: Trist, Eric, 1981. The evolution of socio-technical systems. Toronto, Ontario: Ontario Quality of Working Life Centre.

More recently, there is a special issue on socio-technical systems in: Barko, William and Pasmore, 1986, Special Issue: Sociotechnical systems: Innovations in designing high-performing systems. Journal of Applied Behavioral Science. 22. 195-360.

A more recent assessment of sociotechnical interventions is presented in: Beekun, Rafik I. 1989. Assessing the effectiveness of sociotechnical interventions: Antidote or fad? Human Relations, 42, 877-897.

[17] The principles are taken from: Cherns, Albert, 1976. "The principles of socio-technical design." Human Relations, 29, 783-792

planners/supervisors/foreman/manager is concentrated in boundary activities.

VI - Information Flow. This principle states that information systems should be designed to provide information in the first place to the point where action on the basis of it is needed.

VII - Support Congruence This principle states that a system of social support should be designed to reinforce the behaviours which the organization structure is designed to elicit.

VIII - Design and Human Values. This principle suggests that the objective of a design should be able to provide a high quality of work, by recognizing the efficiency needs of technical system and individual needs for growth, development, learning, and involvement.

IX -- Incompletion. If a system framework is used in designing organizations, there is a need to recognize that design is a reiterative process.

Applications of these theoretical ideas are illustrated with several types of organizational changes -- in the technical system, job designs, participation of workers, shift schedules, support systems, organizational philosophy, and collective agreement.[18]

Applying these Principles How do we take steps to implement these concepts to capture the unique features of an organization? The following is a listing of some of the steps that might be considered. Typically, the process includes: (i) encouraging organizational leaders and members become more aware of the concepts and cases which have been applied elsewhere, (ii) developing a coordinating or steering committee to oversee and control the project, (iii) developing a philosophy statement or corporate philosophy which outlines the principles of the change and ways it will be managed, (iv) selecting project sites and change teams who will manage the projects within those areas, (v) carrying out a systems and socio-technical analysis by the project team, (vi) defining the changes to be implemented, (vii) implementing the proposals for change, and (viii) diffusion of the proposals to other parts of the organization.

3. CONCLUSION

This paper suggests that systems theory might be useful for handling complex problems, especially ones where mechanistic communications has failed. It recognizes the need to focus on the organization's functioning and on the interrelationship between each department's functioning. Systems communications is more promising if it focuses on each departments critical requirements in relation to other departments.

---

[18] Examples of Canadian applications are contained in: Cunningham, J.B. and White, T.H. 1982. Quality of working life: Contemporary cases. Ottawa: Labour Canada.

This paper has also identified some of the principles of socio-technical theory which might be applicable to the design of organizations. In offering these principles, it provides certain references which illustrate how these principles were applied and can be applied.